BUILDERS' GUIDE

to Energy Efficiency in New Housing

Housing & Urban Development Association of Canada

HUDAC

Ontario

Ministry of Energy

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FOREWORD

The Housing and Urban Development Association of Canada and the Ontario Ministry of Energy, through their joint sponsorship of this Builders' Guide, have shown a fine example of private and public sector cooperation to achieve a common goal – reduced energy consumption.

HUDAC took the responsibility for coordination and quality of the Guide development, ably assisted on the Steering Committee by the Ontario Ministry of Housing, the Ontario Ministry of Consumer & Commercial Relations, Ontario Hydro, the Ontario Council of HUDAC, and, of course, financially and technically, by the Ontario Ministry of Energy.

The consultant study team of the I B I Group, Scanada Consultants Ltd. and Hooper and Angus Associates Ltd. has applied its knowledge and analytical capabilities in site planning and architectural design, building science, construction, mechanical equipment and marketing.

The Guide's contents and presentation are intended to emphasize day-to-day knowledge which will help the Canadian builder achieve practical results in the field of energy conservation.

Hugh L. Molland

Hugh L. Molland
Chairman, HUDAC/Ontario Ministry of Energy Steering Committee

Preface

Canadian home builders and home owners can play an important role in conserving our energy supplies. The present dwelling stock consists of about 7 million units. During the 1980's this will increase by some 30%. The manner in which builders design and construct these units will have an important effect on the national consumption of home energy.

Most builders find their time is fully occupied in dealing with day-to-day activities of financing, selection and buying of lots, construction, and sales. Little time is left for actively researching the building science options and technology to improve energy efficiency. Although considerable literature is available on the theory of energy use and conservation in buildings, there is no comprehensive guide for Canadian builders that offers practical suggestions related to market conditions.

The purpose of this guide is to give the average Canadian builder practical information and guidance in the area of energy conservation in new housing. It offers useful suggestions for planning, designing and building a more energy efficient home. Builders can use these suggestions at their own discretion to improve the quality of their dwellings and provide cost saving benefits for the buyers.

The guide provides advice on energy efficient techniques suitable for low-rise housing (singles, semis and duplexes, row housing, and walk-up three-storey apartments), which is, and is expected to remain, the most common form of housing built in Canada.

Most building codes across Canada already provide for a relatively high level of energy efficiency, representing significantly higher energy conservation over code requirements of the mid 70's and earlier. For purposes of this guide provisions of the 1979 Ontario Building Code were taken as the basis upon which to develop and evaluate improvements. Such improvements beyond code standards can be shown to be desirable under certain conditions because energy prices are continuing to rise and future supplies are in question.

The Guide provides what builders say they need: information on what to do combined with consideration of costs. The Guide emphasizes **what** to do, **how** to do it (indicating special construction procedures or considerations where warranted), and **why** it is important. Detailed background information and building science theory have been kept to a minimum; there are excellent publications available for those builders interested, and the National Office of the Housing and Urban Development Association of Canada has a bibliography prepared as part of the development of the Guide.

The Guide is organized in nine sections to provide clear recommendations with a minimum of cross referencing from one section to another.

Metric units are used for all insulation values and heat loss calculations. The symbol 'R' designates 'RSI' wherever used. Appendix E provides definitions of abbreviations and some conversion factors from metric to imperial units.

Note:
The Guide makes reference to CMHC Builders' Bulletins currently in use. These are updated from time to time. Users of the Guide should ensure that they are referring to the latest version of these Bulletins, by checking with local CMHC offices.

Contents

Section 1
Energy Conservation in Housing

This section provides a brief background to the use of energy for housing in Canada. It notes the proportion of total energy use devoted to housing, reviews trends in energy sources for new housing, illustrates energy cost trends and projections and outlines possible energy savings in new housing.

1.1 Present Energy Use in Canada

As background to efforts for improving energy conservation in new housing, it is useful to review energy demand in Canada. Figure 1.1 shows where the energy is used. Industry takes 28%; transportation requires 26%; residential[1] uses take 20%. Commercial needs and energy generation are less significant, at 11% to 12%.

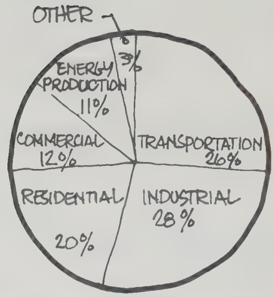


FIGURE 1·1 ENERGY USE BY ACTIVITY SECTOR

There are three principal energy sources used in the residential sector. Figure 1.2 indicates that oil is by far the most significant source, supplying 56% of the needs. Natural gas presently supplies 25% and electricity 19%. Wood and propane supply a small proportion.

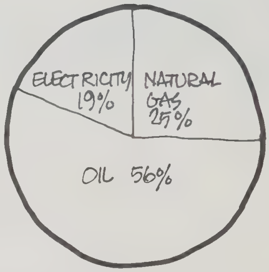


FIGURE 1·2 ENERGY SOURCES FOR THE RESIDENTIAL SECTOR

1.2 Trends in Energy Sources for New Housing

The above figures for residential energy use apply to the total existing housing stock. These do not reflect current trends for **new** housing. A strong influence on the energy sources selected for space heating and domestic hot water heating in new housing is the availability and cost of energy, which varies by geographic area. The following regional trends in the selection of energy sources for low-rise housing have been evident in recent years, and are likely to continue.

- **Natural Gas in Ontario, the Prairies, and B.C.:** The ready availability and relatively lower cost of natural gas in Alberta and the existence of adequate pipeline facilities to transport it has resulted in the use of this fuel in a large proportion of new housing in Ontario, the Prairies and B.C.

- **Electricity in Quebec, Newfoundland and New Brunswick:** electricity is the most common energy source for new housing in Quebec, Newfoundland and New Brunswick. The first two provinces have hydro-electric power sources. New Brunswick builders favour electricity, probably because of lower home installation costs.

- **Oil in Prince Edward Island and Nova Scotia:** these Maritime provinces have lately turned to imported fuel oil for space heating in the majority of new housing. This has been found to be more economical than using the oil to generate electricity because of production and transmission losses.

These trends are seen to be continuing, but modifications could take place as energy sources are developed and tapped, and as mechanical equipment is developed and improved.

1.3 Energy Costs

The costs of all of the above sources of energy have risen significantly in recent years, and this trend is expected to continue. Recently concern has been

1 includes farm uses

expressed about the reliability of supplies. This section presents a comparative review of the rates of increase in energy costs using Toronto costs as an example, and then illustrates expected cost projection ranges up to 1985.

1.3.1 Trends in Energy Costs

In reviewing trends in energy costs, it is useful to compare annual rates of growth in cost by energy source: oil, natural gas, and electricity. It is also instructive to compare the rates of increase with the general inflation rate (rate of growth in the Consumer Price Index) and the rate of growth of personal disposable income (income after taxes have been paid).

Figure 1.3 shows how energy costs and other economic indicators have grown from 1965 to 1978, giving each item on the graph an index of 100 in 1965.[2] By comparing the index for the items at any point in time the effect of differing growth rates becomes apparent. For the period 1965 to 1978 note the following:

- Personal disposable income grew much faster (3.5 times the level it was in 1965) than the consumer price index (about 2 times the level it was in 1965).
- Home heating oil prices had almost the same growth rate as those of natural gas and electricity until about 1970-1971. After that time home heating oil prices began to increase much faster, mainly due to factors outside of Canada.
- Electricity and natural gas prices have increased at approximately the same rate over the period 1965 to 1978, slightly higher than the rate of increase in the consumer price index, but much less than that for home heating oil.

1.3.2 Projections in Energy Costs

Figure 1.3 also illustrates cost projections for the three main sources of space heating energy from 1978 to 1985. Also included is a projection of the growth in the Consumer Price Index.

High, medium and low projections in energy costs from a variety of sources have been reviewed and the figures used have been selected in consultation with the Ministry of Energy of Ontario. Figure 1.3 illustrates the medium rate. For purposes of illustration, the Consumer Price Index is assumed to have an annual rate of growth of 9% (the general inflation rate) over the projection period.

Including this annual rate of general inflation, prices for these energy sources are expected to have the following annual average increases from 1978 to 1985:

- Home heating oil – 12.6%
- Natural gas – 12.5%
- Electricity – 10.5%

Although the actual experience in energy cost increases may not be as smooth as that shown on the curve, it is felt that the **average** annual increase from 1978 to 1985 is as representative as present knowledge permits.

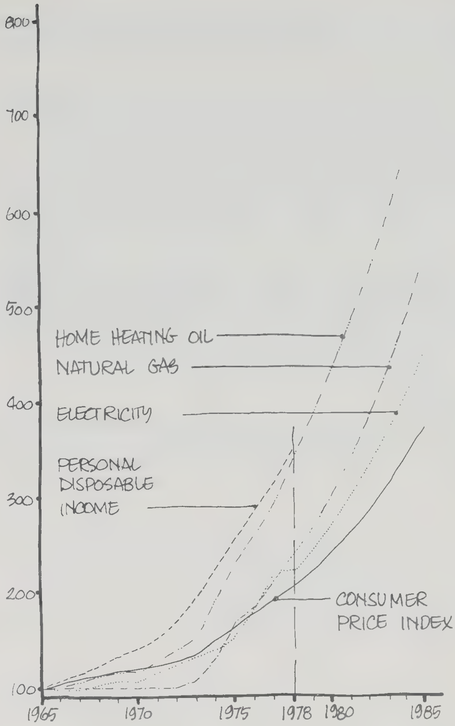


FIGURE 1·3 ENERGY COST TRENDS & PROJECTIONS

2 Toronto Consumer Price Index, Ontario Disposable Income Per Capita Index, and Indices for Residential Fuel Oil, Natural Gas, and Electricity in Toronto.

The significant conclusion is that the rate of energy cost increase will probably continue to exceed the general inflation rate.

Moreover, the projected annual percentage increases in oil and gas costs appear to be larger than the mortgage interest rate, which is usually 1.5 to 3[3] percentage points higher than the general inflation rate (this difference between the mortgage and the general inflation rate is the real cost of borrowing money).

This influences attitudes towards the idea of **investing** in energy saving home improvements, and is reflected in increased consumer concern regarding energy.

1.4 Potential Energy Savings in New Housing

Regardless of the source of energy, many opportunities exist for increasing energy efficiency in new housing by building beyond the requirements of current building codes.

Increasing energy efficiency will reduce annual home operating costs. If these savings are considered as a reduction in mortgage payments, then it is a simple matter to determine what extra home purchase price could be spent on energy-saving improvements with no increase in cost to the home-owner.

In Toronto, a 20% reduction in energy consumption would justify a house priced $700 higher than one built to minimum code requirements, because energy savings even in the first year of operation would offset the increase in mortgage payments.[4] If the house were located in Thunder Bay, where heating costs are higher, it could be sold for a little more than $1,000 over the price of a similar house built to minimum code requirements.

And that is at today's fuel prices. Energy costs will continue to rise, but mortgage payments are relatively stable so the benefits of energy improvements will increase with time. In the above examples the savings in energy costs will exceed the mortgage payments on the extra purchase price by larger and larger amounts in future years.

Because energy cost rise rates have exceeded the inflation rate in recent years and are estimated to continue to do so, the home purchase price premium for energy efficient features can be a sound investment, paying short and long term dividends. Builders who provide and promote these features could have a definite sales advantage. As buyers' understanding of the importance of energy conservation grows along with energy prices, many future purchasers may insist on these features.

Moreover, the growing prospects of future availability problems will increase buyer concern beyond just ensuring that higher first costs are offset by later energy savings. Energy efficiency is therefore an important consumer consideration.

3 For purposes of cost-benefit analyses used in the Guide, the difference between the mortgage interest rate and the general inflation rate was taken as 3%.

4 Example based on a two-storey house of 167 square metres having a mortgage with a twenty-five year amortization period and interest at 10 to 11 percent, and fuel oil costing 13.2¢ per litre.

Section 2
Energy Awareness in the Design of the Home

This section serves as an introduction to various energy efficient measures that can be provided by builders of new housing. It provides background information on heat losses and gains, effects of housing form, internal layout, siting and landscaping on heat loss; presents ways to measure the costs and benefits of energy conservation features, and comments on comfort and user satisfaction.

2.1 Heat Loss and Conservation

2.1.1 The Energy Balance

A dwelling unit is usually in a state of balance regarding energy – the heat gains just equal the heat losses. When this balance does not exist the temperature either rises or falls until a new balance is reached.

Figure 2.1 shows the energy balance for a typical modern house on a cold winter day. Note that only 83% of the heat input comes from the heating system. Over the whole heating season, the heating system contributes an even lower percentage since the total heating requirement (total heat losses) reduces with increased exterior temperatures but the other heat sources (people, appliances, lighting, water heating) remain essentially constant or, in the case of solar heat gains, may even increase. This is illustrated in Figure 2.2 which shows that in the early fall and late spring the heating system may not have to operate at all because all heat losses are made up by these other sources. The heat from these other sources is sometimes called the free heat.

It should be pointed out that Figure 2.2 is a simplified illustration of the interrelationship between heat gains and heat losses. Heat losses follow the weather which, in Canada, never follows a nice smooth curve. The same is true for solar gain. Even the other sources of free heat will vary from day to day. However, this illustration is close enough to demonstrate the principles involved.

For a typical Southern Ontario house insulated to Ontario Building Code requirements, the total purchased heat (shaded area in Figure 2.2) might be about 67% of the total heating requirements over the heating season. If the same house were placed in a colder climate with the same amount of sunshine the total heat losses would increase. This increase would have to be made up by increased operation of the heating system. Thus the percentage contribution of the heating system would increase.

Conversely, if the heat losses were to be reduced by, for example, adding more insulation, the heating system's contribution would be reduced. This is illustrated in Figure 2.3. Note that it is reduced in two ways. Not only is the contribution at any given time in the heating season reduced, but also, the length of the actual heating season is reduced. Thus the seasonal saving from an energy conservation measure will be a somewhat higher percentage than that calculated on a steady state, point-in-time basis.

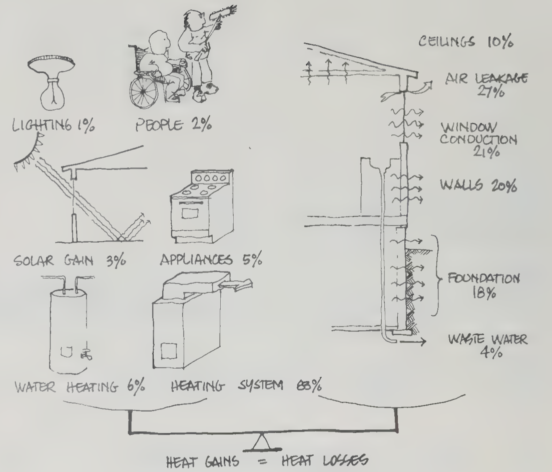


FIGURE 2·1 ENERGY BALANCE ON A COLD WINTER DAY FOR A TYPICAL HOUSE INSULATED TO ONTARIO BUILDING CODE REQUIREMENTS

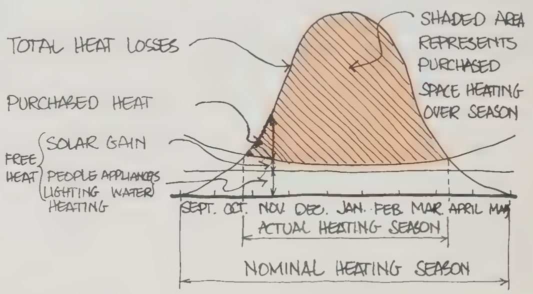


FIGURE 2·2 HEAT GAINS AND LOSSES OVER THE HEATING SEASON.

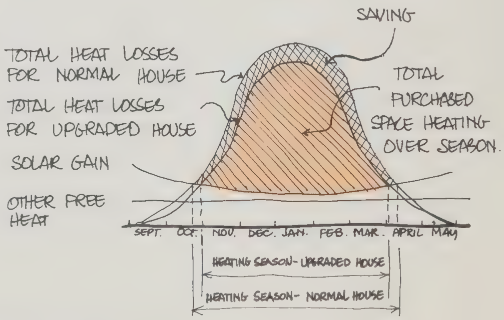


FIGURE 2·3 HEAT GAINS AND LOSSES FOR AN UPGRADED HOUSE

2.1.2 How Heat is Lost from the Dwelling

All of the heat that is put into a building is eventually lost to the outdoors. We cannot stop this loss. All we can do is to slow down the rate at which it occurs.

Heat Transfer

There are three basic ways by which heat is transferred. These are best illustrated by the common occurrences shown in Figure 2.4.

These means by which heat is transferred combine in a variety of ways to transfer heat from the warm interior of the house to the cold outdoors. All three mechanisms take place, for example, in an empty stud space of an exterior wall:

1. Although the air in the space is a poor conductor of heat, a small amount of heat is transferred by conduction through the air.

2. The air in contact with the warm interior surface is heated and becomes lighter than the rest of the air in the space. It rises and moves across to the cold exterior surface where it is cooled, i.e., gives up the heat it had gained. This makes it heavier and thus it falls and moves across to the warm interior surface where the process begins again. A much larger amount of heat is transferred by convection than by conduction.

3. Even if all the air could be removed leaving a perfect vacuum, the warm interior surface would radiate some heat to the cold exterior surface in the same way that the sun's heat reaches the earth.

How Insulation Works

If the stud space is filled with insulation it slows down the transfer of heat two ways. Most importantly convection is virtually eliminated since even most porous insulation materials have sufficient resistance to air movement to overcome the driving force of the temperature difference. Thus the insulation's most important function is to trap air. It is important, however, that the space be completely filled since, if even a small air space is left around the insulation, convection can continue and the insulation may be largely short circuited (Figure 2.5).

The insulation also greatly reduces radiative heat transfer between surfaces by diffusing the radiation. Most insulation materials increase conductive heat transfer since their conductivity is somewhat higher than that of still air. However, the increased amount of heat transferred by this mechanism is much smaller than the reduction in the amount of heat transferred by convection and radiation.

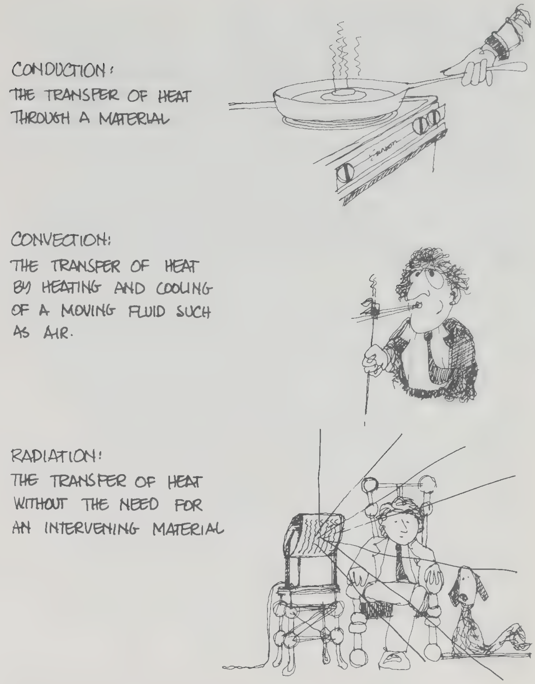


FIGURE 2.4 HEAT TRANSFER MECHANISMS

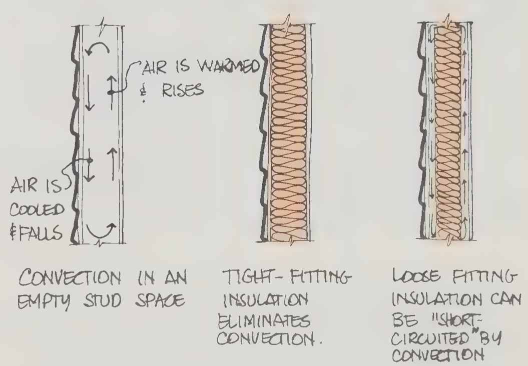


FIGURE 2.5 CONVECTIVE EFFECTS IN A STUD WALL.

Below Grade Heat Loss
Heat transfer through most elements of a building shell operates in the manner illustrated in the above wall example. However one element – the foundation – requires some special mention. The above discussion assumed that there was cold air on the outside of the wall at essentially the outside temperature and that as the air tended to get warmed by the heat coming through the wall it would simply move away, due to convection or wind, and be replaced by more cold air. This is not the case with foundation walls and floors on grade. Their exterior surfaces are in contact with soil.

The soil tends to stay warmer than the outside air in the fall and winter and cooler than the outside air in the spring and summer. It is not fluid like the air and thus tends to be warmed somewhat by the heat coming through the foundation. If it is dry it will act like an insulation; if it is very wet it will act like a highly-conductive heat drain. There is also the factor of snow cover which has a variable insulating effect depending on its depth and moisture content. Because of these complications, heat loss through below-grade portions of foundations is not well understood. Estimates of savings resulting from insulation of foundations therefore cannot be made with the same degree of confidence as with other building elements. The estimates in this Guide are based on the best information currently available.

In addition to the above, this is another type of convective heat loss – that associated with air leakage into and out of the building (this is discussed in Section 3).

2.1.3 How Much to Invest in Energy Conservation Measures
Anything that saves energy saves money, but sometimes the cost can outweigh the benefit. Every millimetre of insulation saves energy. If one were to consider only energy conservation, there would be almost no limit to the amount of insulation that could be justified – or the number of layers of glazing – or the degree of sophistication of heating systems. However, each additional millimetre of insulation saves a little less than the one before but it costs just as much. Common sense tells us that when benefits decrease while costs remain steady there must be some level beyond which the savings do not justify the additional cost.

The difficulty in deciding whether or not to adopt an energy conservation feature stems from the fact that one must compare present costs with future benefits – one pays for the feature now and it saves on heating bills in the future. This is complicated by the fact that the future savings are likely to increase by some unknown amount as energy costs increase in the future.

Builders have the added difficulty of trying to take into account what level of price premium buyers will accept to gain savings by reduced energy use.

There are several methods for dealing with these problems. The Guide emphasizes **payback period analysis,** but also considered other methods: **change in monthly payments** (resulting from energy conservation features), and **life cycle costing.** These are briefly noted below.

Payback Period
The payback method of determining a suitable price premium for energy conservation features focuses on how quickly this price premium is offset by the buyers' savings in energy costs. But what should this time period be?

This period would logically not exceed the length of time that the purchaser owns the dwelling unit. This period varies:

- The first-time buyer of a family home usually owns his home for 3-5 years before moving up to accommodation that will meet his longer term needs (see Section 9).

- The move-up buyer or move-down buyer may occupy his home for a longer period, say 8-10 years or more (see Section 9).

To get buyer acceptance of options requiring a payback longer than the likely period of home ownership, the builder should point out that the value of energy efficient features at the time of resale will probably be at least equal to their initial price plus an amount to account for inflation.

The Guide therefore bases its analysis on the price premium for energy efficient features and concentrates its analysis on determining the length of time required for savings resulting from each energy conservation option to pay back the extra purchase price. By understanding the likely period of ownership of his target market, the builder can select the appropriate options. The likely resale value to the energy efficient features could be considered as a bonus for selecting these features.

Other Methods
Another measure of effectiveness of energy conservation options is the resulting monthly payments in the first year. Some options provide a reduction in the sum of the average monthly payments for principal, interest and energy as compared with the conventional base case or other options (see Figure 2.6). This indicator was considered in the selection of energy conservation options in the Guide.

Life cycle costing can also be used to compare future energy savings over a given number of years with the initial cost premium needed to realize these savings. This approach is a form of payback analysis whereby the payback period is equal to the estimated life of the dwelling or to the amortization period of the mortgage. Life cycle costing was considered but not used in the development of recommendations in the Guide because of this comparative long range aspect for payback.

2.1.4 Energy Conservation and Human Comfort

There are four principal environmental factors which affect the comfort of a person inside a building. In order of decreasing importance they are:

- air temperature
- presence of air currents (drafts)
- temperature of surrounding surfaces
- relative humidity

The significance of each of these factors and the relation of each to energy conservation measures is discussed below.

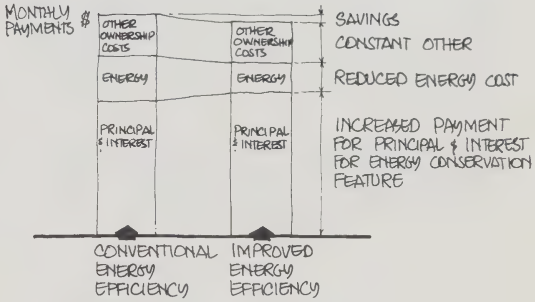


FIGURE 2.6 EFFECTS OF IMPROVED ENERGY EFFICIENCY ON MONTHLY PAYMENTS

Air Temperature
All houses must be equipped with heating systems capable of maintaining a temperature of 22°C on the coldest winter day. Many people are comfortable at lower temperatures than this, permitting a reduction of the indoor temperature which yields a significant reduction in energy consumption. This choice must be left to the home occupant and is largely out of the builder's hands. However, design and balance of the heating distribution system and proper location of the thermostat will help achieve uniform temperatures throughout the house.

Presence of Air Currents (Drafts)
At any given room temperature, moving air will carry heat away from the human body faster than still air and thus will feel cooler. Drafts, rather than air temperature, often cause home owners to turn up their thermostats. Conversely, the absence of drafts will make a lower temperature comfortable. Measures taken to improve the air-tightness of houses, such as those recommended in Section 4, will pay dividends not only in direct energy savings but also in improved occupant comfort – and therefore further energy savings since interior temperature can be lower.

Temperature of Surrounding Surfaces
Even in a warm room a person standing or sitting near a cold outside wall or window will feel cool because his body is radiating heat to the cold surface. A house with very little insulation, even though it might have a furnace large enough to maintain a high air temperature, can still be uncomfortable due to the presence of many cold surfaces. Present insulation standards have virtually eliminated this problem in new homes, however, and further increases in insulation levels must be judged on their energy conserving potential alone.

Windows, on the other hand, even if double-glazed, are much colder than other interior surfaces and any improvements in their thermal resistance will yield a comfort bonus (see Subsection 4.8).

Relative Humidity
The fact that higher relative humidity permits lower temperatures to be tolerated has been stressed so often that it need hardly be repeated here. While this is basically true its importance has been exaggerated well beyond its real significance. According to data published by the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE), it would require an increase in relative humidity of more than 40 percentage points to permit a reduction in temperature of 1°C with equivalent comfort. Yet even in Canada's mildest regions our houses cannot tolerate relative humidity much greater than 40% in the winter. If it were increased to 80%, or any level much above 40%, very serious condensation problems would result.

The truth is that in modern houses, especially when an effort has been made to increase air-tightness using air/vapour barrier techniques such as those recommended in Section 4, there is usually a need to decrease humidity rather than increase it and one or more of the controlled ventilation techniques shown in Section 3 is called for rather than a humidifier. Thus builders should discourage home buyers from following the higher humidity/lower temperature concept.

2.2 Design Considerations

The above introduction provides background to the following design recommendations. All of these design aspects are intended to reduce heat loss; some have little or no premium attached to them, and many can provide for improved occupant comfort. The following recommendations are suggested for use where possible, and are followed by discussion and illustration.

2.2.1 Recommendations

Dwelling Form

- Select the most energy efficient housing type that the market will accept.
- Plan the units to maintain simple compact forms, with the least amount of exterior surface. Avoid complex projections and indentations of heated space in plan and section.
- Avoid extensive use of dormers and garages within heated spaces.
- Use unheated building elements such as garages, vestibules, and storage sheds, to provide visual interest and variety in housing form. These elements can be used effectively as insulating air spaces on the north side.
- Use climate controls in the form of porches (south, west), trellises (south, west), windscreens (on prevailing windward side), awnings (east, south, west), shutters and small greenhouses (south).
- Design shading devices that screen windows from the summer sun, but permit capture of solar heat in winter.

Internal Layout

- Reduce the number of openings in north walls by organizing the dwelling plan so that major windows can be located on other walls, preferably the south wall. Even so, some north wall openings may be required for cross ventilation that will reduce the desire for mechanical ventilation and/or air conditioning in summer.
- Arrange floor plans and house siting to provide winter sunlight to the rooms when it will do the most good – the morning sun to the kitchen and bedrooms, perhaps – the noonday and afternoon sun to the living and dining rooms.
- Place non-living spaces on the north side wherever possible. Spaces such as bathrooms, utility rooms and mud rooms that require little, if any, natural lighting, can be aligned along north walls.
- Make use of passive solar winter heat gains on the south side. Concentrate glass areas on the south elevation, together with protective measures to deal with summer heat and glare; consider using sun rooms and glassed-in porches on the south side; and place slabs and massive elements such as fireplace enclosures so that they can store heat from winter sun's rays passing through south windows.

- Provide unheated vestibules and vestibule doors to reduce drafts in living space.
- Place furnace, furnace flue and fireplace centrally to get maximum advantage of heat transfer from these elements.
- Locate water heater centrally (in plan) with respect to kitchen, bathrooms and washing machine locations.

Siting and Landscaping

- Residential streets should run east-west wherever possible to provide maximum exposure for winter solar heat gain for houses on either side of the street.
- Select south or west-facing slopes, clear of shading from neighbourhood houses and tall coniferous trees, wherever possible.
- Choose sites where north and west winter winds are at a minimum or where there is protection from them.
- In siting the dwelling on the lot take advantage of any existing vegetation or earth forms to create windbreaks by placing the dwelling unit in the wind 'shadow'.
- Plant deciduous trees to provide summer shade for dwelling walls, windows (especially those on the west), and roof. Check with a landscape expert to ensure that the trees are located so that future root growth will not damage foundation walls.
- Use ground cover plants rather than paving on ground surfaces immediately adjacent to the south and west walls to reduce glare and reflected radiation.
- Plant windbreaks of coniferous trees to protect dwellings from prevailing winter winds. To be most effective these trees should be planted in at least two and preferably three rows in staggered formation because of their conical shape. The most effective location of a windbreak is up-wind at a distance of 1.5 to 2 times the height of the building.
- Use earth berms as windbreaks. Be sure to provide adequate drainage on the dwelling side of the berm.
- Use hedges, fences, and walls to funnel summer breezes through the house.

2.2.2 Dwelling Form

Generally, the greater exterior surface area a building has, the higher its heat losses will be. Figure 2.7 shows the relative heat losses for various forms of dwellings, all with approximately the same amount of livable floor area and all insulated to Ontario Building Code minimum requirements.

The bungalow, two-storey house, and split-level entry unit are all free standing. The bungalow has the highest heat loss because it is relatively spread out and has the highest ratio of exposed surface area to volume. The

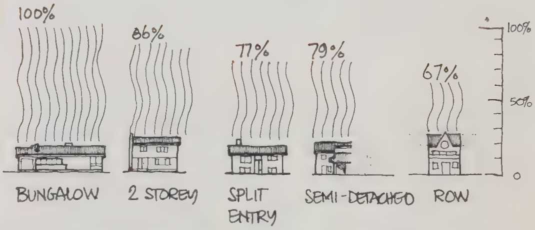


FIGURE 2·7 RELATIVE HEAT LOSSES BY DWELLING TYPE
HEAT LOSSES ARE SHOWN AS A PERCENT OF HEAT LOSS OF THE BUNGALOW OF SAME HABITABLE FLOOR AREA.

bungalow is therefore the least energy-efficient house form.

The two-storey house more closely approaches the shape of a cube and therefore has a smaller ratio of surface area to volume. For this reason it requires less energy for space heating than a bungalow with the same floor area.

The detached split-level entry home is similar to the free standing two-storey house in its compact shape, but has a smaller total surface area to be heated. The split-level entry house is therefore more economical to heat than the two-storey house.

The semi-detached house is similar to the detached single family house, but as one of its walls is not exposed to the weather, it is more energy efficient.

Row housing units have both long walls sheltered from the weather (except for end units), making this the most energy efficient form of low rise housing.

But despite the wide variations in energy efficiency of these dwelling types, energy efficiency is only one factor considered by purchasers in choosing a home. A number of specific measures presented in this Guide can improve the energy efficiency of each of the housing forms discussed above.

The lessons to be learned from comparing alternative dwelling unit types also apply to selecting the form of each individual dwelling.

Simple compact forms reduce the ratio of surface area to volume (Figure 2.8), and each projection or wall angle increases the area of exterior surface where heat can escape. An attached garage with heated space above it, for instance, exposes the floor of the overhead rooms to the cold and increases heat loss. Dormer windows also increase the surface area to be insulated, without increasing the floor area; and they are difficult to insulate thoroughly because of the irregular surface areas forming the dormer projections (Figure 2.9).

The repeated use of a simple housing form is not very attractive to purchasers, but interesting variations can be achieved by the use of unheated building elements without sacrificing high energy efficiency. Elements such as garages, vestibules and storage sheds can be planned around the main living space where they not only add visual interest, but also shelter and, to some extent, insulate the walls to which they are joined (Figure 2.10). These elements are particularly useful on north walls where they can serve as a buffer to winter winds.

Another way of providing visual interest is to use structural elements that offer climate control. These include porches, trellises, windscreens, awnings, shutters and small greenhouses (Figure 2.11). These elements improve the environment as well as the appearance of the home at no increase in heat loss.

FIGURE 2·8 SIMPLE FORM

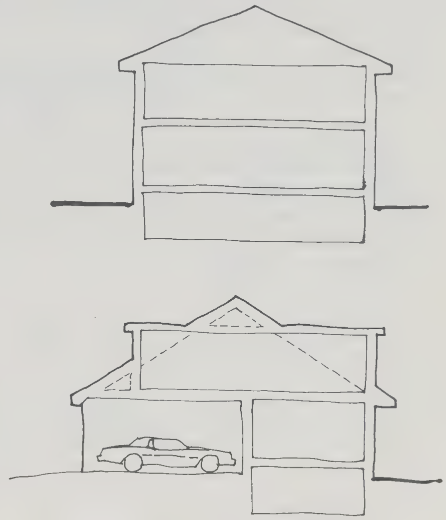


FIGURE 2·9 GARAGES AND DORMERS

GARAGES PROJECTING INTO THE FORM OF THE DWELLING, AND DORMERS, TEND TO INCREASE INSULATED SURFACE AREA IN COMPARISON TO FLOOR AREA.

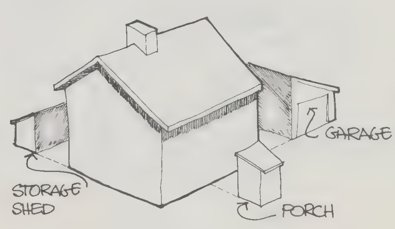


FIGURE 2·10
UNHEATED ELEMENTS

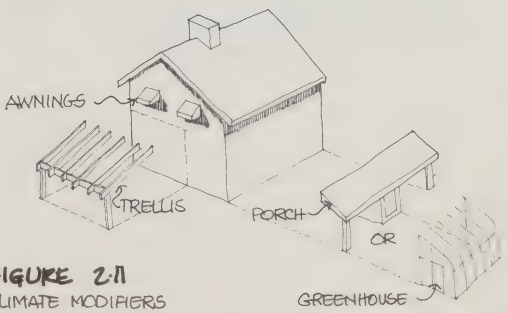


FIGURE 2·11
CLIMATE MODIFIERS

Built-in shading elements can improve energy efficiency while making the house more attractive. Correctly designed, they protect windows from heat buildup due to summer sun, but make the most of solar gains during the winter. Figure 2.12 shows various alternatives. Figure 2.13 shows typical window dimensions for various room types and gives the factors used to calculate overhang dimensions according to degree of latitude of the site.

2.2.3 Internal Layout

The floor plan of the dwelling influences the amount of energy it uses. Knowing how this happens can help the builder select the most efficient layouts for his homes.

Windows on the north side lose heat in winter, those on the east and west sides also lose heat, but get some heat back to the house from the sun. Builders should select plans that do not place the larger windows, such as those for living and dining rooms, on the north side. If north-facing windows are needed, they should be kept as small as possible. However, some openings on the north may be useful to provide cross ventilation and reduce the desire for mechanical ventilation and/or air conditioning in the summer.

Floor plans should be designed to place rooms and windows where they can take maximum advantage of available sunlight. It is preferable to have sun in the kitchen in the morning than in the late afternoon when dinner is being prepared. Morning sun is also preferred for bedrooms. Noonday and afternoon sun is most useful in living and dining rooms. Used in this way, sunlight can reduce the household demand for lighting and heating (Figure 2.14).

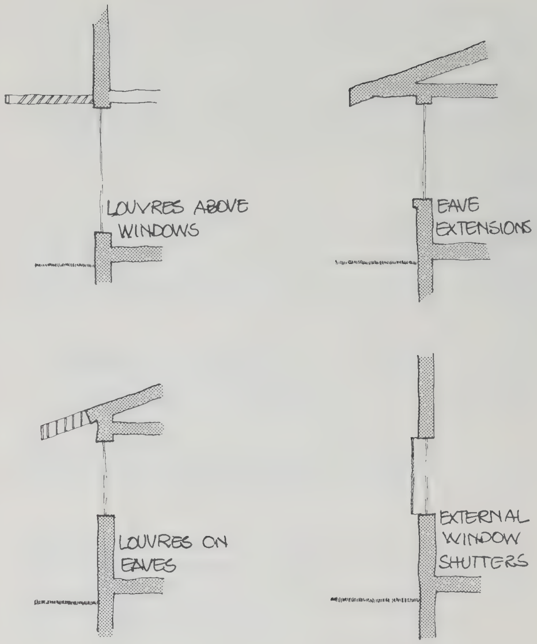


FIGURE 2·12
ELEMENTS PROVIDING WINDOW SHADING

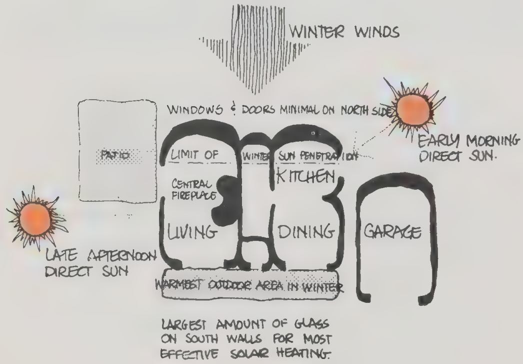
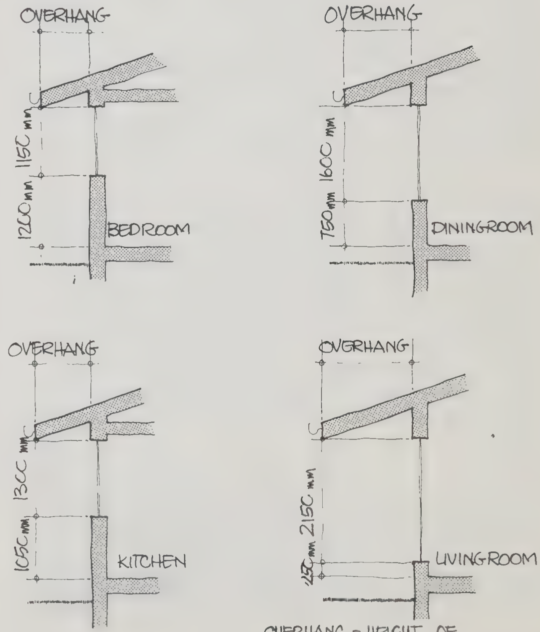


FIGURE 2·14 LAYOUT FOR WINTER SOLAR GAIN



OVERHANG = HEIGHT OF WINDOW OPENING × F

LATITUDE	FACTOR F
40°	0·71
45°	0·85
50°	1·02

FIGURE 2·13
EFFECTIVE SHADING

Non-living spaces such as bathrooms, utility rooms and mud rooms should logically be placed on the north side, because these rooms require little, if any, natural lighting.

Windows on the south side can actually provide a net heat gain in winter by allowing solar heat to enter the home. East-west streets provide the best opportunity for winter solar heat gains. Careful selection of a dwelling plan to fit the orientation of the lot will allow the large windows of the living and dining areas to take advantage of the south exposure (see Figure 2.15).

Builders can take advantage of solar heat gain in a number of other ways:

- fit large south facing windows with shading devices to protect against summer sun heat build-up (Figures 2.12, 2.13);
- use sun rooms and glassed-in porches as heat traps;
- locate large masonry elements such as floor slabs and fireplaces where the winter sun will strike them. The solar heat they store during the day will be released at night.

Vestibules can improve comfort by reducing drafts when the front door is opened, especially in small homes where the entry opens directly into the living space.

Furnaces and fireplace chimneys radiate heat, much of which is lost if they are located on outside walls. Placing chimneys in a central location keeps more of this heat in the house and also reduces the maximum length of warm air ducts or hot water heating pipes.

Similarly, heat loss from hot water pipes can be reduced if the tank is located close to points of use such as the kitchen, bathroom and laundry area.

2.2.4 Siting and Landscaping

Careful siting and landscaping can also improve energy efficiency in new housing at little or no additional cost to the home buyer.

In addition to the general climate of the area, each site has its own immediate climatic conditions governed by its view of the sun, exposure to prevailing winds, landscape and topography. All of these have a small but significant effect on the air temperature, wind and solar radiation around the dwelling. These effects can be improved or modified through design.

Whether or not builders have an influence on street alignment, they should keep in mind that lots on east-west streets provide the best opportunity for maximum southern exposure for winter solar heat gains (Figure 2.16).

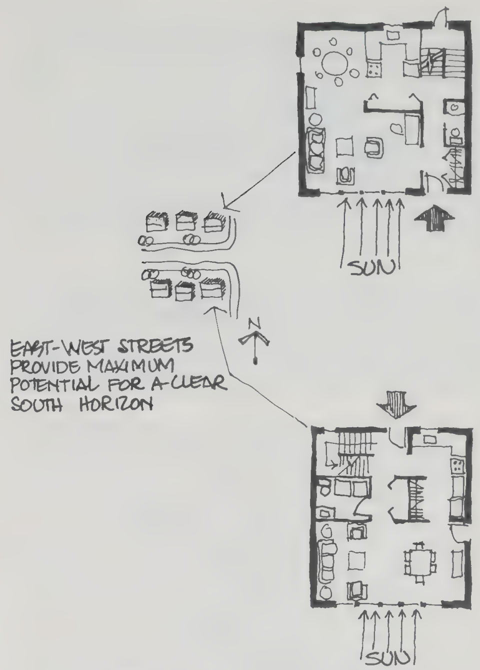


FIGURE 2·15 STREET ORIENTATION & ITS EFFECT ON FLOOR PLANS

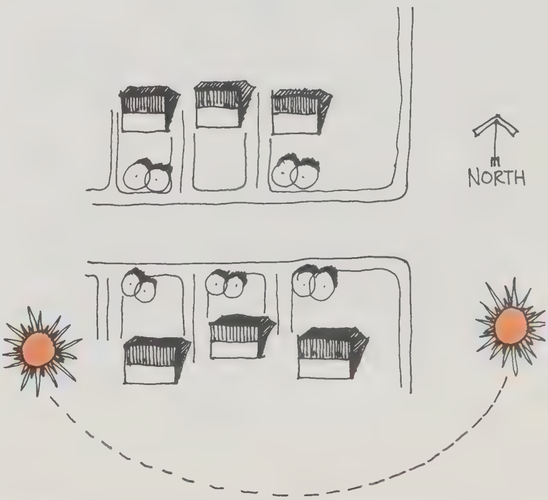


FIGURE 2·16 EAST-WEST STREETS PROVIDE MAXIMUM POTENTIAL FOR WINTER SOLAR GAIN.

Similarly, south- or west-facing slopes are preferable to flat sites. Sites that are shaded on the south by tall coniferous trees or neighbouring buildings should be avoided, of course.

Other factors to consider when selecting lots include exposure to north and west winter winds, and the presence of any existing trees, hedges or earth forms that would provide shelter against winter winds. Builders should select those lots that minimize wind exposure.

Landscaping can improve the energy conservation features of any site. Builders should plan landscaping as part of the total dwelling, carefully considering orientation and types of plant material. The assistance of a qualified landscape specialist is recommended.

Deciduous trees provide shade in summer, then lose their leaves and admit sunlight in winter. They reduce window heat gain by blocking direct summer sunlight penetration. This form of shading is particularly important for west-facing windows because normal overhangs are not as effective against low-angled sun's rays in the late afternoon. Shade provided by trees also lowers the ground surface temperature so heat gain through a tree shaded window is reduced by less heat radiation from the ground and by the cooler air temperatures (Figure 2.17). Care should be taken to locate trees sufficiently far away from the dwelling so that at full growth the root system will not damage foundation walls. This distance is generally one-half the height of the mature tree. A plant expert should confirm this for specific plant material.

Another way to reduce glare and reflected radiation adjacent to homes is to use ground-cover plants, rather than paving, on ground surfaces beside south and west walls (Figure 2.18).

Coniferous trees can provide a winter wind break (Figure 2.19). To be most effective they should be planted in at least two and preferably three rows in staggered formation, because of their conical shape. The best place for a wind break is up-wind at a distance of 1.5 to 2 times the height of the building. At this distance the wind will be reflected up and well over the building, reducing pressure on the building's windward side and a pulling action on its leeward side.

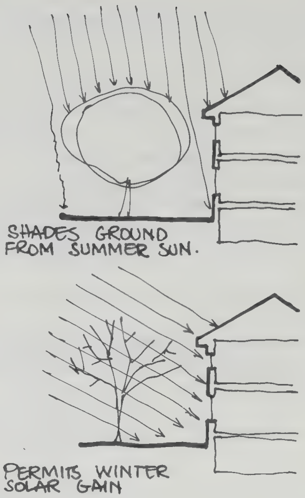


FIGURE 2.17 REDUCTION OF SUMMER GLARE & GROUND RADIATION

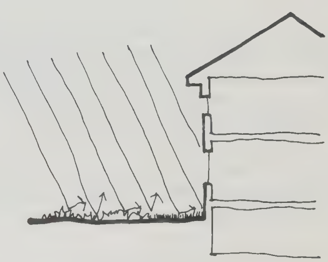


FIGURE 2.18 REDUCTION OF GLARE BY GROUND COVER.

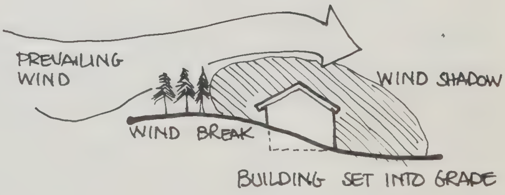


FIGURE 2.19 PROTECTION FROM WINTER WINDS

Another means of wind protection through landscaping is the use of earth berms. Excess earth from excavation and site grading could be used for this purpose. Care must be taken to provide for adequate drainage on the dwelling side of the berm, however.

Summer breezes can help reduce the need for mechanical ventilation or air conditioning. Careful placement of hedges, fences, and walls can be used to funnel these breezes where they will do the most good (Figure 2.20).

Figure 2.21 summarizes many of the possibilities for energy conservation related to site planning and landscaping. Many of these features can be included in builder's homes at little or no cost if the builder is aware of them during the site selection and planning process.

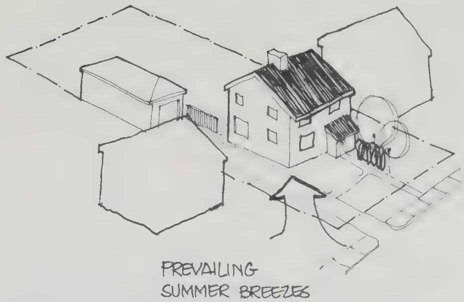


FIGURE 2.20
FUNNELLING SUMMER BREEZES

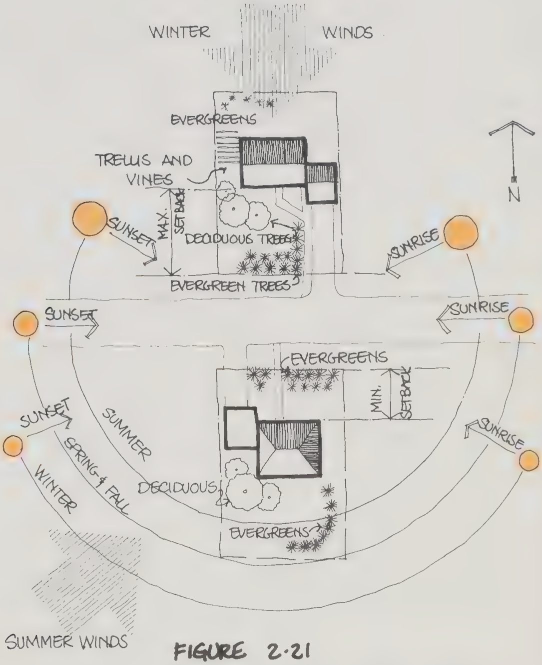


FIGURE 2.21
LANDSCAPING FOR CLIMATE CONTROL

Section 3
Air Tightness, Ventilation and Moisture Control

This section deals with an important but often forgotten factor in determining the energy efficiency of a house – ventilation. The need for Canadian housing to make the change from accidental to controlled ventilation is explained and the means of achieving this are illustrated. The importance of ventilation for the control of humidity is also explained.

3.1 Recommendations

- Build houses as tightly as practical in order to minimize accidental ventilation. This is accomplished mainly by careful installation of the air/vapour barrier and by careful installation of good quality windows and doors.
- Incorporate a means of providing ventilation in a controlled way so that only the minimum amount necessary to control air quality and humidity levels and supply combustion air for furnaces need be provided.
- Inform purchasers or renters of the importance of controlling humidity and how the ventilation system may be used to do so.
- Incorporate a heat recovery device in the ventilation system where high moisture loads necessitate unusually high ventilation rates or in very cold areas where even moderate ventilation rates result in high energy costs.

3.2 Ventilation

By ventilation we mean the replacement of the air in the house with fresh air from outside. In most houses it occurs whether we want it to or not and at a rate which is determined by characteristics of the house rather than the needs of the occupants.

Ventilation is essential to provide fresh air for the occupants, remove dust, tobacco smoke and household odors, and supply combustion air for a fuel-burning furnace or fireplace. One of the most important functions of ventilation is often overlooked. During the winter months it controls the humidity in the house by removing the water vapours produced by cooking, washing, bathing – even breathing. If this is not removed, the humidity will build up to the point where serious condensation problems are inevitable.

3.2.1 Amount of Ventilation

How much ventilation is required? The answer depends on the number of occupants in the house, their lifestyle, the type of heating and the outdoor temperature. A house occupied by a couple who are away at work all day would require far less ventilation than a similar house occupied by a family with three small children. A house where the family takes a lot of baths needs more ventilation than a house where fewer baths are taken.

In most of our houses there is very little we could do to control ventilation even if we did know how much was required. Largely accidental, it occurs through holes in the structure and is dependent on the strength of the wind, the difference between indoor and outdoor temperatures, the operation of the furnace, and the natural buoyancy of heated air. The only control the occupants can exercise is to increase ventilation when it is too low by opening windows or operating exhaust fans, and this requires their active and informed

participation. Unfortunately, very few home owners understand the relationship between ventilation and humidity.

Ventilation was of little concern in the past because most houses had much more than they needed and fuel was cheap. Today, however, two important factors indicate that this attitude must change:

1. With rising energy costs we can no longer afford to waste energy unnecessarily by allowing too much ventilation. Every cubic metre of warm household air that leaks out and is replaced by cold outside air takes with it an appreciable amount of heat.

2. The growing frequency of condensation problems indicates that many new houses have too little ventilation.

3.2.2 Controlled Ventilation
How can this be changed? The answer is to reduce accidental ventilation (by making the shell of the house as tight as possible) and replace it with some form of controllable ventilation. Some houses are already being built as airtight as it is practical to make them (i.e. with the minimum air leakage). Builders of these houses are using good building practices similar to those described in Subsection 4.1 along with high quality windows, doors and weatherstripping. However, if no additional steps are taken to provide ventilation, the houses are likely to experience serious moisture/humidity/condensation problems. This is especially true if they are electrically heated and have no chimney to force a certain amount of ventilation.

Various ways of achieving controlled ventilation are described and illustrated below. In order of increasing complexity they are –

- outdoor air duct to return air plenum
- dummy chimney
- exhaust fans
- central exhaust system

The more complex methods cost more but provide a greater degree of control.

Outdoor Air Intake to Return Air Plenum
This method is already being used by some builders although they do not always include a damper. When the damper is omitted the control is lost. This method is much better than simply opening windows, because the outdoor air is heated and filtered before being distributed to the house (Figure 3.1).

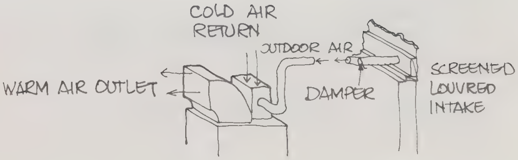


FIGURE 3·1 OUTDOOR AIR DUCT TO RETURN AIR PLENUM WITH DAMPER.

Recommendations

- The Homeowner should be instructed to gradually close the damper over a period of several days during cold weather until condensation just begins to appear on windows, then re-open it a small amount.

- Insulate the duct to avoid condensation on its outer surface.

Dummy Chimney
Unlike the previous method, this method can be used in houses without forced warm air heating systems. It can be located at any convenient point in the house. Warm

air rises up the dummy chimney due to stack effect. This creates a negative pressure in the house which draws in outside air through leaks in the building shell. In a very tight house it might be necessary to open a window a small amount for this method to be effective (Figure 3.2).

Recommendations

- The homeowner should be instructed to gradually close the damper over a period of several days during cold weather until condensation just begins to appear on windows, then re-open it a small amount.
- Seal the duct well and insulate it where it passes through the attic.
- Seal the opening in the ceiling which the duct passes through (see Subsection 4.1).
- Ensure that the duct DOES NOT terminate in the attic but vents right to the outdoors.
- Extend the duct high enough above the roof to clear expected snow accumulation.
- Have the inlet end in the basement since there is some risk of rain and condensation dripping down the duct. There is also some risk of cold drafts coming down the duct under certain unusual conditions.

Exhaust Fans

This method is quite common and need not be dwelt upon here except to note the good installation practices shown in Figure 3.3 which are often neglected. The National Building Code requires that one or more exhaust fans with a total capacity of at least 3 m^3/min be installed in every dwelling that does not contain a fuel-fired heating appliance. There is a wide range of quality among the exhaust fans on the market. Only those complying with Canadian Standards Association Standard C260.2 can be recommended.

Recommendations

- Follow the installation practices shown in Figure 3.3. Further details on installation of exhaust fans can be found in CSA Standard C260.1.
- Use only fans complying with CSA Standard C260.2.

All of the above methods of controlled ventilation have the disavantage of being manually controlled and thus requiring the occupants to have both the willingness to control them and the knowledge of when and how to do so. This can be partially overcome by installing, in a central location, a good quality humidistat (i.e. one which incorporates a nylon sensing element) to operate fans or motorized dampers. Even when this is done, the occupants must still be convinced of the need to avoid high relative humidity in the winter and to set the humidistat appropriately (see Subsection 3.2).

Central Exhaust System

This is obviously a very complex and expensive system likely to be used only in more expensive housing. It provides very positive, minute-by-minute control of humidity. In a tightly-built house it permits reduction of

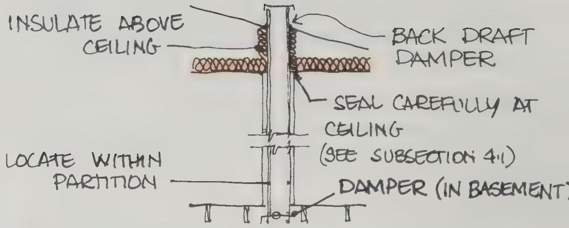


FIGURE 3.2 DUMMY CHIMNEY WITH DAMPER

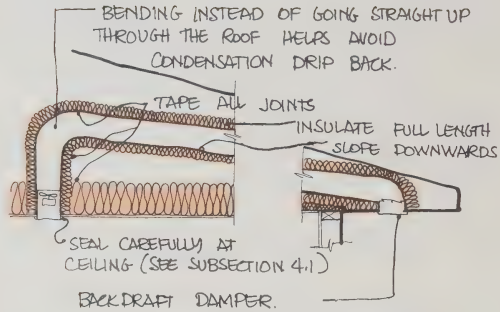


FIGURE 3.3 EXHAUST FAN

the ventilation down to the minimum necessary for such control. It can also be quite effective in cooling the house on summer nights. It lends itself to the use of a heat recovery device to warm the in-coming air with heat from the exhaust air (Figure 3.4).

Recommendations

- Provide inlets in at least the kitchen, bathroom, laundry area and main living area.
- Provide a blower at least capable of exhausting all the air in the house in one hour. Required capacity can be estimated using the following formula:
  Blower Capacity (m^3/min) = $\frac{\text{Floor area including basement } (m^2)}{26}$
- To reduce noise annoyance use a fan with a Sone rating[1] of less than 2.0 and locate it in the basement.
- Locate the outside air intake in the basement or similar area not frequently occupied so that the cold incoming air will not be annoying and can gradually warm up as it moves into other parts of the house. Keep plumbing pipes out of this area. Where there is a forced warm air heating system, the cold air intake can enter the return air plenum as in Figure 3.1.
- Fit the intake with a damper and have the installer adjust it so that with the blower running there is a slight negative pressure in the house but not exceeding about 50 Pascals (Pa). If the negative pressure is too high, uncomfortable drafts will be caused around windows and doors.

Note:
Any fan-operated ventilation system has the potential to starve an oil or gas furnace of the air it needs for combustion. Where such a system is used, controls should be incorporated which prevent the ventilation fan(s) from operating when the furnace is on. Alternatively, a separate combustion air supply for the furnace may be needed. Requirements for combustion air supply can be found in the following Ontario Government Regulations:

Ontario Fuel Oil Equipment Installation Regulation,
O. Reg. 298/72.
Sections A1-A6 inclusive

Ontario Gas Utilization Regulation O. Reg. 254 under the Energy Act.
Sections 38-44 inclusive.

3.3 Sources and Control of Moisture

The previous subsection indicated that one of the important functions of ventilation is to remove water vapour from the house. Typical sources of that water vapour are listed below.

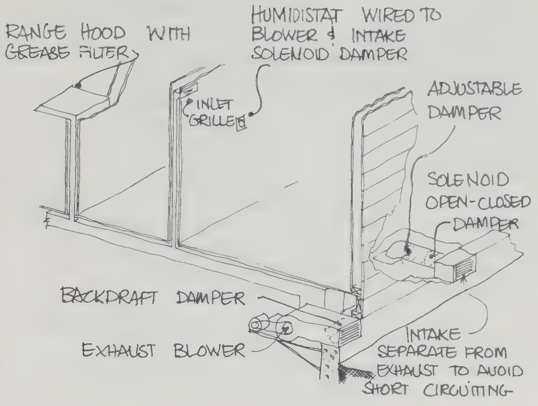


FIGURE 3·4 CENTRAL EXHAUST SYSTEM

Source	Amount of Water Vapour Generated
Cooking (3 meals)	1 kg per day
Dishwashing (3 meals)	0.5 kg per day
People (family of four)	5 kg per day
Bathing – shower	0.25 kg each time
Bathing – tub	0.05 kg each time
Clothes washing	2 kg each time
Clothes drying	12 kg each time

Looking at these figures one can see that on any given day more than 20 kg of water vapour could be put into the air in a house. On a cold winter day, relative humidity higher than about 35% will create condensation even on double-glazed windows. A 100 m^2 house in which the air is at 21°C and 35% relative humidity will contain about 3 kg of water vapour suspended in the air. Thus if this relative humidity is not to be exceeded, 17 kg of water vapour must be removed from the air in some way.

3.3.1 Control

At present the only practical means of removing water vapour from houses is ventilation. The warm humid air is pushed outside, taking its load of water vapour with it, and is replaced by cold and dry air from outside. As mentioned in Subsection 3.2 the inside air takes heat with it and the incoming air must be heated; but it is necessary to pay this energy penalty to keep the humidity at a level which the fabric of the house can tolerate. It may be possible, however, to reduce this penalty substantially by using some means to recover the heat from the outgoing air (see Subsection 3.4).

Why not use a dehumidifier? It might seem logical to use a dehumidifier to control winter humidity and prevent condensation, since this would reduce the need for ventilation. Even the energy used to run the dehumidifier would remain within the house as a form of electric heating. Unfortunately, the dehumidifiers currently available for household use are designed only for summer conditions. The amount of water vapour they can condense out of the air is very small once the relative humidity goes below about 60%, which is much too high to prevent condensation problems in winter. Research is currently underway to develop a dehumidifier suitable for winter conditions but for now, ventilation remains the only practical means of controlling humidity.

3.3.2 Importance of Control

What would happen if the water vapour were not removed? Failure to control humidity at reasonable levels can lead to disastrous results.

Surface Condensation

The first sign that humidity is too high is condensation on cold surfaces such as windows.

If this warning is not heeded and humidity goes uncontrolled, the next stage could be the growth of mildew or other fungus on the interior surfaces of exterior walls and ceilings. This often shows up first in closets or behind drapes where the lack of air circulation causes slightly higher humidity in a very localized area; but it can also affect quite large areas. It is often accompanied by an unpleasant odour.

Concealed Condensation

While the foregoing problem can be very serious, at least the results are visible. Once the cause is

understood, corrective action can be taken before the problem becomes too serious. More insidious are the hidden problems that occur if a significant amount of vapour leaks into the shell of the building, where it can condense on cold surfaces and cause a number of undesirable things to happen:

- the insulation can get wet and lose all or most of its thermal resistance
- the wood structure can rot to the point where it is no longer able to support any load
- gypsum board and other materials can crumble and collapse.

Because these problems occur within the fabric of the building, they may build up undetected until they reach serious proportions and become very difficult and expensive to correct. Therefore any reasonable means of avoiding these problems is worthwhile. To do so it is necessary to prevent the water vapour from getting into the building shell. This is the purpose of a vapour barrier although this name doesn't fully describe its function. Vapour barriers are dealt with in the next subsection but before leaving the subject of moisture generation one further concept should be dealt with.

3.3.3 Concealed Condensation and Humidity Level
It is practically impossible to create a perfect vapour barrier. Some leakage of water vapour into a building shell will always occur, whether the humidity in the house is high or low. All of the materials in the shell can tolerate a certain amount of moisture. Often, if the moisture that accumulates over the winter is not too great, it will dry out over the summer and the house will go through a mild annual wet and dry cycle with no significant consequences. But if the humidity in the house is allowed to get too high, the moisture accumulation will not dissipate and the house fabric will deteriorate. Thus even in a very carefully built house it is necessary for the occupant to realize the importance of controlling humidity during the heating season. It is also necessary for the builder to provide him with the means of doing so.

3.4 Function of the Vapour Barrier (Air Barrier)

There are two mechanisms which try to drive the water vapour through the building shell. The first is **vapour pressure.** Because there is more water vapour in the air inside the house than in the outside air during the winter months, the difference in **vapour pressure** tends to force the water vapour to **diffuse** through the materials making up the shell (Figure 3.5).

Water vapour can pass through most building materials, to some degree, but those classified as vapour **barriers** allow only a very small amount to pass through. They are said to have very low permeability.

The second mechanism by which water vapour is forced through the building shell is **air movement.** There are often differences in **air pressure** from inside to outside the house created by stack effect, the operation of fans or the action of the wind. When the air pressure inside is greater than that outside, air will tend to flow outwards through any holes or cracks in the building envelope, carrying with it the water vapour it contains (Figure 3.6). Only in recent years have we

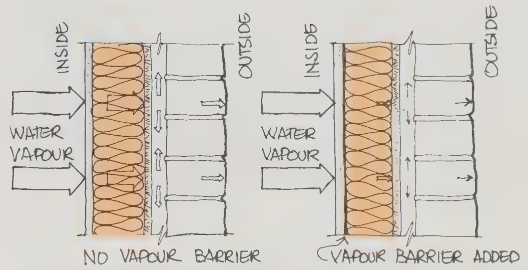


FIGURE 3·5 VAPOUR DIFFUSION – THROUGH THE MATERIALS

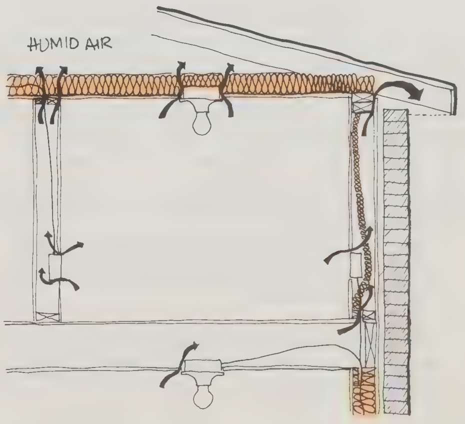


FIGURE 3·6 AIR LEAKAGE – THROUGH THE HOLES

discovered that this air leakage is more important than diffusion in the transmission of water vapour through the building envelope. Thus building scientists today tend to talk about air barriers rather than vapour barriers.

Example: Relative importance of vapour diffusion and air leakage in unwanted movement of water vapour

Assume:
- Interior air is at 21°C and 40% relative humidity
- 10 m^2 ceiling of 9 mm gypsum board
- 2 coats of enamel paint
- Crack at edge of ceiling 1.5 mm wide x 1.2 m long
- Typical winter conditions regarding outdoor temperatures and relative humidity

Water vapour moved by diffusion in 100 days: 3 kg
Water vapour moved by air leakage in 100 days: 20 kg

Because air leakage is much more important than vapour diffusion if follows that the continuity of the air/vapour barrier is much more important than its permeability. Fortunately, the material that has been most commonly used as a vapour barrier – polyethylene film – also makes an excellent air barrier, since it comes in large room-height sheets that can be applied to create a nearly continuous air/vapour barrier if used correctly.

Subsection 4.1 shows some details and procedures for the installation of an air/vapour barrier. No doubt there are other methods that would work equally well. The important thing to keep in mind when installing an air/vapour barrier is that its primary purpose is to block the movement of air from inside the house into the shell of the house. A properly installed air/vapour barrier also saves energy by reducing unwanted, accidental ventilation.

3.5 Heat Recovery

Once one invests in a mechanical ventilation system such as that shown in Figure 3.4 and considers the cost of the heat that goes out with the exhaust air, it's natural to think about recovering that heat. Ventilation air heat recovery has been used on commercial and industrial buildings for many years but, except for a few experimental installations, it has not been used on houses. Most heat recovery methods involve some form of air-to-heat exchanger that transfers heat from the exhaust air to the intake air as it passes through adjoining ducts. Other methods involving the use of heat pumps can also be used, but air-to-air heat exchangers are more advanced at the moment.

Air-to-air heat exchangers require two conditions for efficient heat recovery:

1. The intake and exhaust flows must be close enough together that they can both go through the heat exchanger.

2. The intake and exhaust flows should be very nearly equal in order to have the most effective exchange of heat.

If we think of the house as an air-tight flask (Figure 3.7. A) it becomes apparent that the flows through the intake inlet and the exhaust outlet must be equal since the total flows in and out of the flask must be equal. However, if we introduce leaks into the flask (Figure 3.7. B), the flow through the intake inlet drops below that in the exhaust outlet.

This latter situation is the case in a house and thus the intake flow will always be less than the exhaust flow with a resulting decrease in heat transfer effectiveness. For maximum heat recovery using an air-to-air heat exchanger, therefore, every practical step should be taken to make the house more nearly airtight.

There are few residential scale air-to-air heat exchangers commercially available yet in Canada, although they are available in Europe.

Although it cannot be stated with certainty at this early stage, studies indicate that heat recovery using air-to-air heat exchangers is unlikely to be cost effective in the near future in most circumstances. One exception would be cases where a large number of occupants in a small house creates a high moisture load which requires a high rate of ventilation to remove. Also, in very cold regions, even a relatively low rate of ventilation imposes a severe energy cost which can be alleviated with heat recovery.

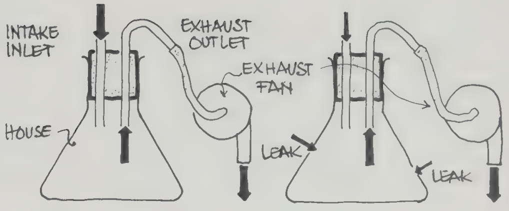


FIGURE 3.7 INTAKE AND EXHAUST FLOWS

Section 4
Options for Improving the Building Shell

The building shell consists of the walls, roof, windows and doors – all the elements which separate the indoor environment from the outdoor environment. It can be improved to yield worthwhile savings in energy by increasing its thermal resistance and by making it more nearly air-tight. But these improvements should only be undertaken when costs, benefits, possible negative consequences and alternate methods of improvement have been fully considered. This Section addresses these considerations for each of the elements of the building shell.

4.1 Installing the Air/Vapour Barrier

Installing the air/vapour barrier is an important part of construction for energy efficiency. This subsection suggests a range of good practice techniques.

4.1.1 Recommendations

- Use large-sheet polyethylene for air/vapour barriers, applying it in wall-height sheets with only vertical joints and as few of these as possible. It should be at least 0.10 mm thick.
- Lap all joints in the air/vapour barrier by one framing space or seal them with tape or caulking compound.
- Carefully seal all openings in the air/vapour barrier to maintain its continuity.
- Locate attic hatches in carport or garage ceilings, in end gables or some place other than in the insulated ceiling of the house.
- Eliminate electrical outlets and fixtures on insulated ceilings and exterior walls to the extent permitted by codes.

4.1.2 General Considerations

In Subsection 3.3. it was explained that the most important function of the air/vapour barrier is to block the movement of warm humid air from inside the house into the shell of the house and that, in order to do so, it must be as nearly continuous as possible.

Therefore the methods of installing the air/vapour barrier included in this subsection do not include any which involve the use of the type of vapour barrier which is attached to insulation batts since the chances of attaining any reasonable degree of continuity when the vapour barrier has joints every 400mm or 600mm are not very good.

All of these methods, therefore, involve the use of large sheets or rolls of polyethylene film. While 0.05 mm polyethylene has sufficiently low permeability to act as a vapour barrier, it is quite easily torn. A minimum thickness of 0.10 mm is recommended.

One common weak point in the air/vapour barrier is the attic access hatch in the ceiling. This is most easily avoided by locating the hatch someplace else, such as in the insulated celing of an attached garage or carport if this connects with the house attic. It could even be located in an outside gable wall. There is no code requirement that the access hatch be located within the house. But if it is necessary to locate the hatch inside the house, it must be insulated and weatherstripped (a National Building Code requirement).

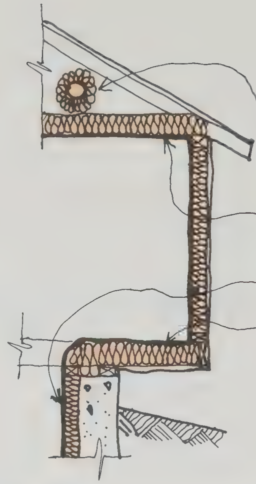


FIGURE 4·1 LOCATION OF AIR/VAPOUR BARRIER

* AIR/VAPOUR BARRIER IS NORMALLY NOT REQUIRED ON FLOORS WITH PANEL-TYPE SUBFLOOR SINCE THE SUBFLOOR PROVIDES AN ADEQUATE AIR BARRIER AND DOWNWARD LEAKAGE OF WARM AIR IS LIKELY TO BE MINIMAL IN ANY CASE. BUT WHEN IT IS USED, IT SHOULD GO ON TOP.

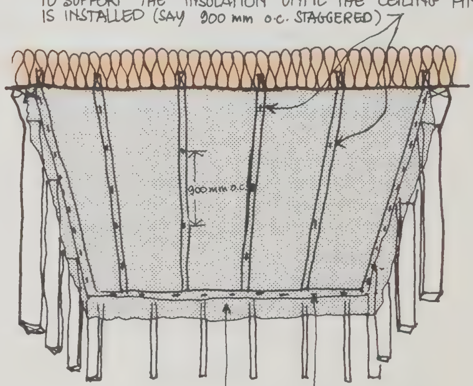


FIGURE 4·2 INSTALLATION OF AIR/VAPOUR BARRIER ON CEILINGS

Where a sealant is called for in the following figures, a good quality non-hardening sealant such as one of the butyl-based types should be used.

See Figures 4.1 to 4.11 inclusive for illustrations of good practice.

Note: The air/vapour barrier techniques recommended here, if followed faithfully, will result in a house with a high degree of air-tightness which will require some form of controlled ventilation if condensation problems are to be avoided. This is especially true if the house is electrically heated. See Subsection 3.2 for a discussion of controlled ventilation.

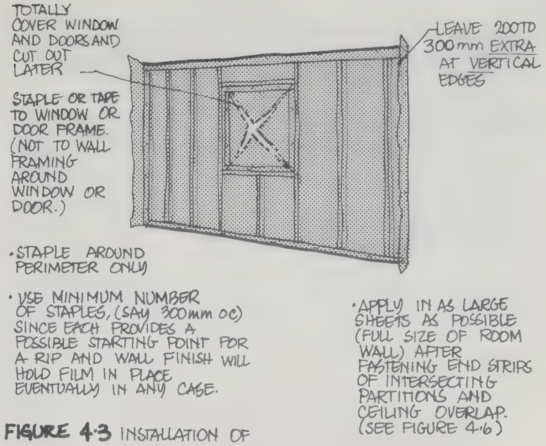
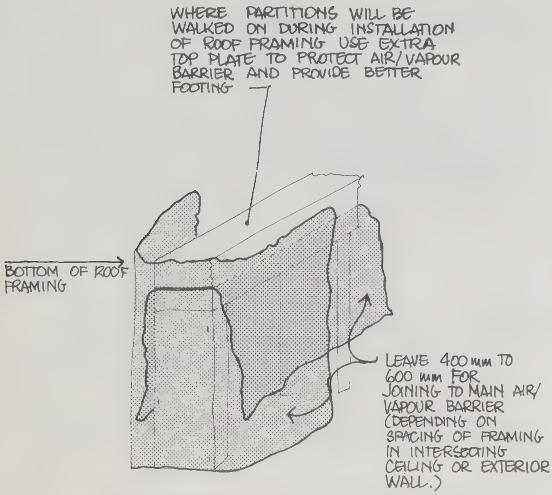


FIGURE 4.3 INSTALLATION OF AIR/VAPOUR BARRIER ON EXTERIOR WALLS



INSTALLATION OF AIR/VAPOUR BARRIER ON TOP AND ENDS OF INTERIOR PARTITIONS WHICH INTERSECT INSULATED WALLS OR CEILINGS.

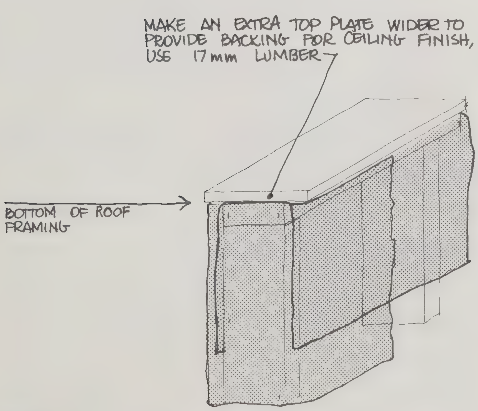


FIGURE 4.4 INSTALLATION OF AIR/VAPOUR BARRIER ON TOP AND ENDS OF INTERIOR PARTITIONS – WHERE PARTITION IS PARALLEL TO ROOF FRAMING

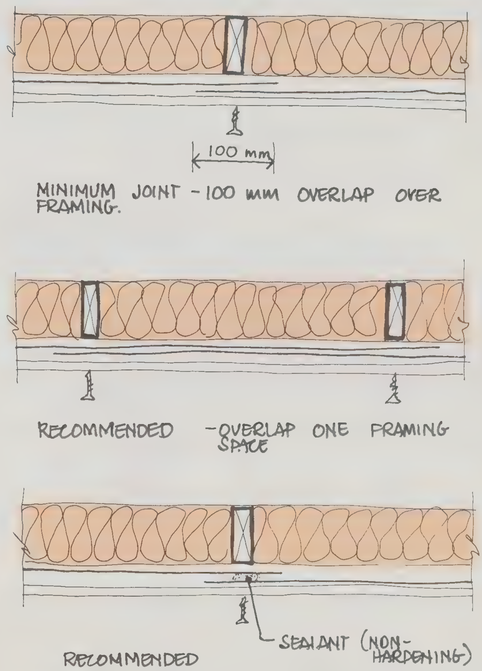
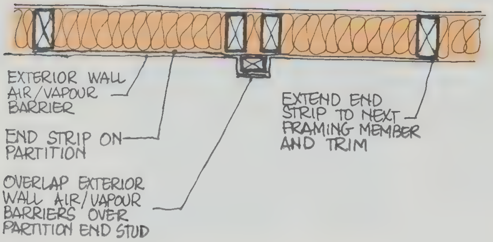
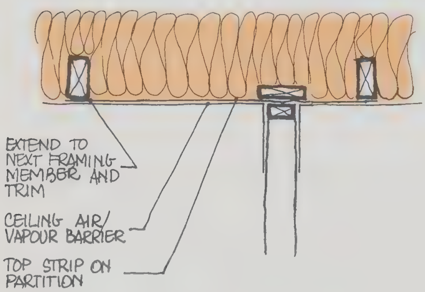


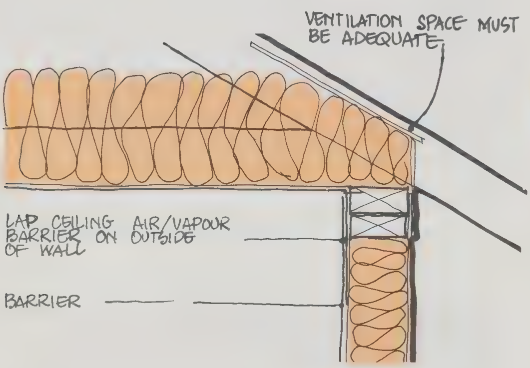
FIGURE 4.5 AIR/VAPOUR BARRIER JOINTS



A) EXTERIOR WALL – INTERIOR PARTITION INTERSECTION



B) CEILING – INTERIOR PARTITION INTERSECTION



C) CEILING – EXTERIOR WALL INTERSECTION

FIGURE 4·6 AIR/VAPOUR BARRIER JOINTS AT INTERSECTIONS

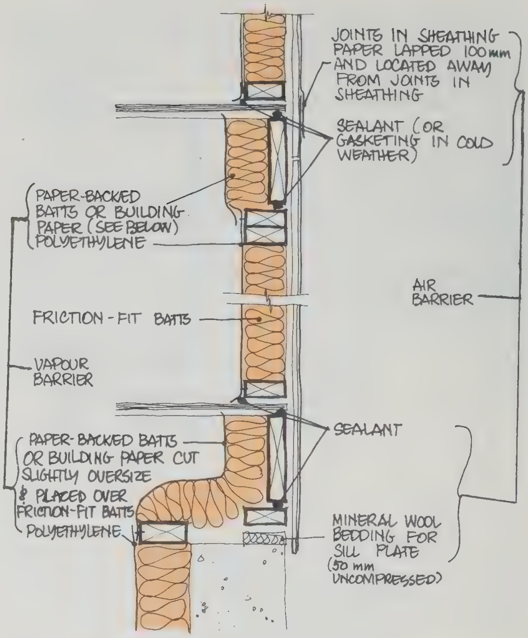


FIGURE 4·7 EXTERIOR WALL – FLOOR INTERSECTIONS

NOTE: ACHIEVING A CONTINUOUS AIR/VAPOUR BARRIER AT THIS LOCATION IS VERY DIFFICULT, SO THE AIR AND VAPOUR BARRIERS ARE SEPARATED.

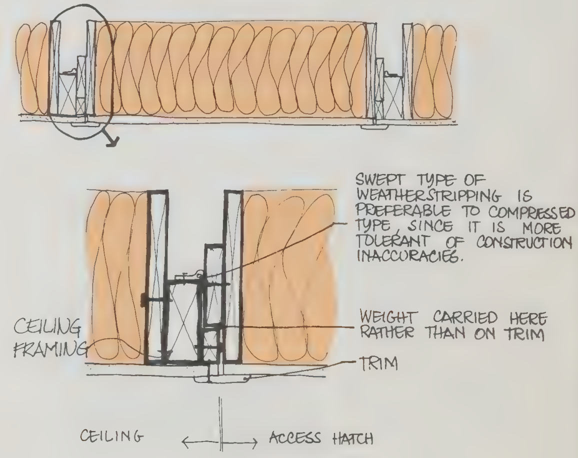


FIGURE 4·8 SUGGESTED ATTIC ACCESS HATCH DETAIL

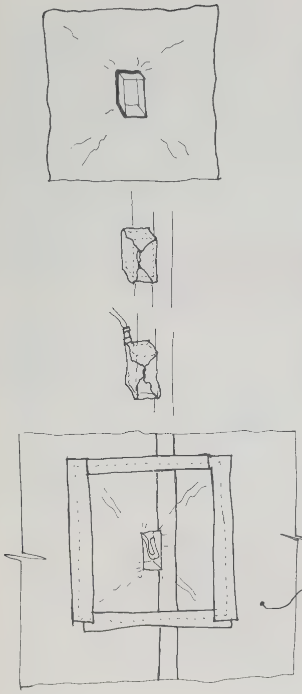


FIGURE 4·9 MAINTAINING CONTINUITY OF THE AIR/VAPOUR BARRIER AT ELECTRICAL BOXES.

NOTE: WHEREVER POSSIBLE AVOID LOCATING ELECTRICAL BOXES ON EXTERIOR WALLS AND INSULATED CEILINGS

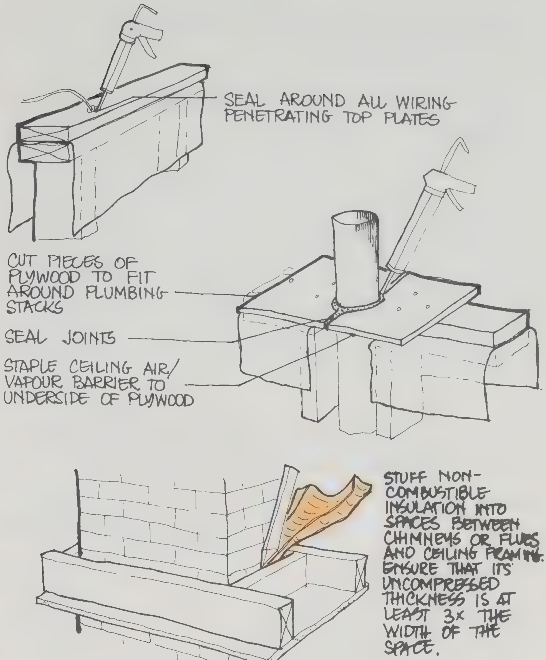


FIGURE 4·10 MAINTAINING CONTINUITY OF THE CEILING AIR/VAPOUR BARRIER

NOTE: DO NOT RELY ON THE CEILING INSULATION TO STOP AIR MOVEMENT. IT MAY ONLY FILTER IT!

POTENTIAL FIRE HAZARD: KEEP INSULATION AT LEAST THREE INCHES AWAY FROM THE SIDES OF RECESSED LIGHT FIXTURES, DO NOT PLACE INSULATION OVER SUCH FIXTURES SO AS TO ENTRAP HEAT.

4.2 Insulation

The following subsections present options for increasing the thermal resistance of the insulated portion of the building shell. In addition to general descriptions of materials and techniques, the estimated construction cost premiums and energy savings of a number of options are given in tabular form.

4.2.1 Calculating R Values

Although the Ontario Building Code specifies only the R value of the insulation which must be added to a building assembly, all of the components of the assembly influence its thermal resistance. The exterior cladding, sheathing and interior finish add to the thermal resistance of an insulated frame wall, while the studs reduce it. CMHC Builders' Bulletin No. 267 and the 'Measures for Energy Conservation in New Buildings' published by the Associate Committee of the National Building Code specifies the total thermal resistance of the assembly, including the contributions of exterior cladding, sheathing and interior finish but **not** including the effect of wood framing. The reduction in overall R value due to the presence of framing need only be taken into account when calculating heat losses in order to determine the required capacity of heating equipment or estimating annual heating costs.

On the basis of the above, then, calculating the R value of a building assembly is simply a matter of adding up the R values of the individual components and making allowance for the R value of the thin films of still air in contact with the surfaces. R values for various materials

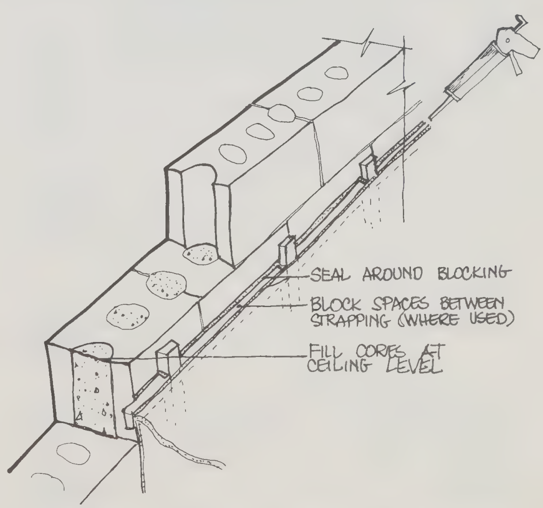
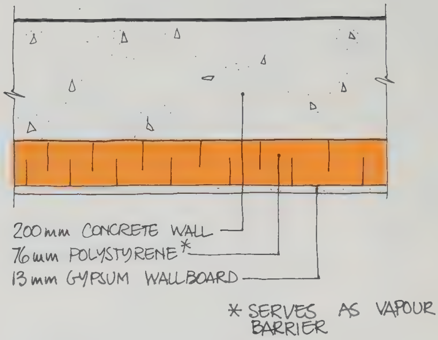


FIGURE 4·11 TREATMENT OF MASONRY PARTY WALLS

are given in Appendix B. The following examples, Examples i to iv illustrate the use of those values and the graph in Figure 4.12.

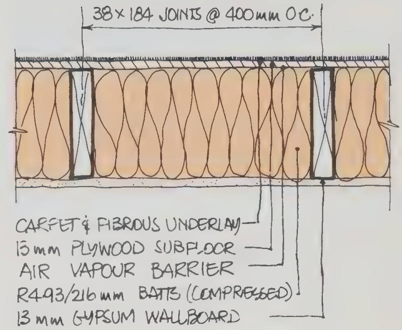
Example i Foundation wall above grade

Component	R Value (m² °C/ W)
Outer surface film	0.030
Concrete 0.00045 × 200	0.090
Polystyrene 0.0347 × 76	2.637
Air/vapour barrier	0
13 mm gypsum board – 13 × 0.0062	0.081
Inner surface film	0.120
Total R Value	2.958



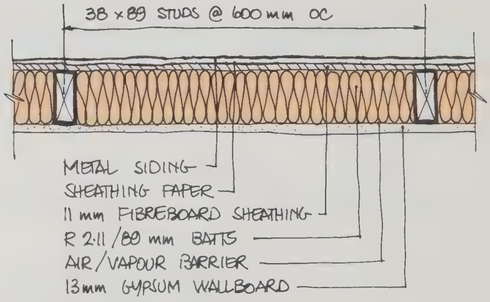
Example ii Floor over unheated space filled with batt insulation

Component	R Value (m² °C/ W)
Upper surface film	0.162
Carpet & fibrous underlay	0.366
13 mm plywood – 13 × 0.0087 =	0.113
R4.93 Insulation – compressed	4.506
13 mm gypsum board – 13 x 0.0062 =	0.081
Lower surface film	0.030
Total R Value	5.258



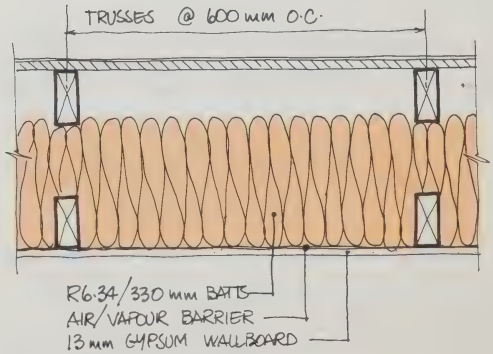
Example iii Exterior wall with conventional sheathing

Component	R Value (m² °C/ W)
Outer surface film	0.030
Metal siding	0.123
Sheathing paper	0.011
11 mm fibreboard – 11 × 0.0165 =	0.182
R2.11 Insulation	2.110
Air/vapour barrier	0
13 mm gypsum board – 13 × 0.0062 =	0.081
Inner surface film	0.120
Total R Value	2.657



Example iv Ceiling

Component	R Value (m² °C/ W)
Bottom surface film	0.105
13 mm gypsum board – 13 × 0.0062	0.081
Air/vapour barrier	0
Insulation	6.340
Top air film	0.030
Total R Value	6.556



It is often necessary to use insulation batts in cavities which are not as deep as the batts are thick. For example 150 mm batts might be used in a wall built with 38 x 140 studs. The resulting compression reduces the thermal resistance of the batts but the reduction in the R value is not proportional to the reduction in thickness. Figure 4.12 shows an approximate relationship between amount of compression and reduction in R value. For example, a 150 mm batt compressed into a 140 mm cavity is compressed to 93% of its free thickness but still retains about 96% of its original R value.

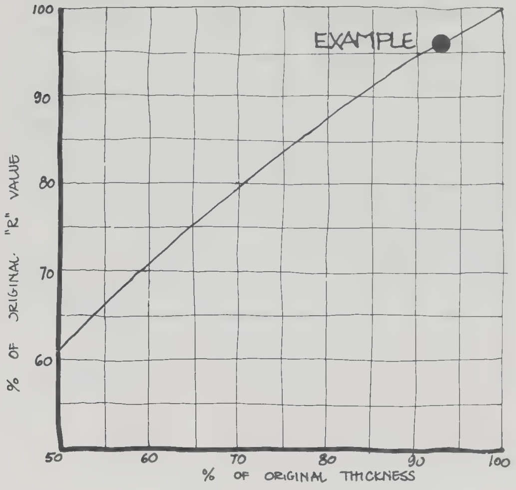


FIGURE 4·12 EFFECT OF COMPRESSING BATT INSULATION

4.2.2 Analysis of Insulation and Construction Options

Subsections 4.3, 4.4, 4.5, 4.6 and 4.7 present tables analyzing options providing improved energy efficiency. The numbers in the tables are based on comparison with a base case house (Figure 4.13) which just complies with the insulation requirements of the Ontario Building Code,[1] 1978 Edition. The characteristics of this house are as follows:

Storeys:	2
Floor Area:	140 m^2
Insulated Floor Area:[2]	20 m^2
Insulated Wall Area:	142 m^2
Insulated Ceiling Area:	70 m^2
Foundation Wall Perimeter:	33.5 m
Foundation Exposure above Grade:	460 mm

	R Values[3]
Foundation	R 1.4 (insulation added) to 600 mm below grade
Floor	4.45
Wall	2.54
Roof	5.16

The R values above and those in Tables 4.3, 4.4, 4.6, 4.7, 4.8 and 4.9 include insulating sheathing, exterior cladding and interior finish but are not reduced for the effect of framing. Exterior cladding and interior finish are kept constant throughout to facilitate comparison since the choice is likely to be dictated by market preference rather than energy considerations. Where different exterior claddings or interior finishes are contemplated, the R value must be recalculated as outlined in the examples. However the choice of exterior cladding or interior finish is unlikely to affect the relative merits of the various insulation options.

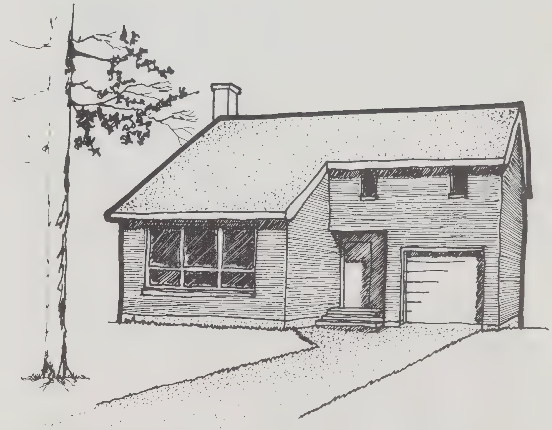


FIGURE 4·13
BASE CASE HOUSE

The cost figures shown in the tables are estimated builders' costs including material, labour, overhead and markup and are based on smooth flow but not necessarily high volume production (as opposed to custom building). The costs given are on a 'per house' basis using the base case house. The energy savings are based on average 1978 Ontario energy costs.[4] The payback periods were calculated assuming –

- the cost of money is 3% more than the inflation rate

1 See Appendix C for summary of Ontario Building Code Requirements.

2 This is due to having the garage within the dwelling volume. This feature was chosen only for purposes of illustrating options for insulated floors. In practice, garages within the dwelling volume should be avoided to reduce heat loss.

3 Again all R values are in metric units $m^2 {}^\circ C/W$.

4 13.2¢/L for No. 2 fuel oil.
10.6¢/m^3 for natural gas
2.6¢/kWh for electricity.

- energy costs will rise as shown in Figure 1.3 up to 1985 and beyond.

They were then rounded upwards to the nearest year.

Note that although the payback periods for a number of options are rather long the added cost of incorporating many of these options in the original construction is only a few hundred dollars. They provide cheap insurance against unexpected future increases in energy costs and are therefore perhaps more marketable than the payback period alone would indicate, especially in parts of the house, such as floors and walls, that are difficult to upgrade afterward. If the cost premium of any of the options is included in the mortgage, the total outlay on monthly mortgage payments plus the cost of heating in the first year is either negligible (i.e. less than $2.00) or is decreased.

4.3 Foundations

The builder is faced with a number of decisions regarding the insulation of foundations:

- What type of insulation?
- How much?
- How far below grade?
- On the inside or outside of the wall?
- Is it worthwhile insulating the floor?

Close study of the options, costs and savings in Tables 4.1 and 4.2 following Subsection 4.3.10 will provide guidance on some of these questions from an economic point of view. Because there are so many variables, the options included in these tables were chosen to illustrate trends rather than to attempt to cover all the possible combinations comprehensively. Savings associated with insulation methods not included in the tables can be approximated using the method outlined in Appendix A. In a further effort to reduce the variables to a workable number, all options are based on basements with the same floor-to-joist height and with the walls projecting the same amount.

In addition to economics, there are a number of practical considerations which must be taken into account. These are discussed following the recommendations below.

4.3.1 Recommendations

- In choosing a method of insulating foundations the builder should be guided not only by payback but also by the compatibility of the method and materials with his construction process.

- Project the foundation as little as possible above-grade.

- Insulate crawlspaces by insulating the surrounding walls rather than insulating the floor above.

- Do not insulate basement floors unless the foundation is in very wet soil or is very shallow.

- When applying insulation to the exterior of foundation walls, choose a material which is moisture resistant, such as extruded polystyrene or rigid closed-cell urethane board, and protect it above-grade with parging or asbestos cement board. Apply the insulation directly against the

foundation wall, as opposed to horizontally outward from the wall.

- When applying insulation to the interior of foundation walls, protect the insulation with dampproofing, an air/vapour barrier and an interior finish.

See Payback Charts A and B for summary analysis of options. The annual heat loss factor (H.L.F.) shown expresses the amount of energy flowing through a one metre wide vertical strip of wall from subfloor to slab. Note 1 in Subsection 4.3.10 explains the significance of H.L.F. in more detail.

4.3.2 Preserved Wood Foundations

It is not appropriate in this Guide to address all the advantages and disadvantages of various types of foundation construction – preserved wood vs. poured concrete vs. masonry. There are many factors, some of which are still controversial, so we have listed preserved wood foundation options in a separate table with a separate base case. While it is clear that wood foundations are more easily insulated than others, it has been presumed that the choice would be determined primarily by a number of other factors, such as availability of materials and market acceptability.

4.3.3 Amount of Projection Above-Grade

It is generally more difficult and costly to insulate foundation walls than frame walls. Thus they will tend to have lower thermal resistance.

Since the above-grade portion of the foundation wall loses more heat than the below-grade portion and also loses more heat than the superstructure walls because of its lower thermal resistance, it makes sense to keep the height of this above-grade portion to a minimum. On the other hand, if the basement is too low in the ground, it will be necessary to resort to window wells or eliminate windows entirely. Where basement windows are necessary from a marketing point of view, it is better to have them above-ground than to incur the cost and problems resulting from using window wells. However, the foundation wall should not project further above-grade than necessary to accommodate windows. All the options in Tables 4.1 and 4.2 following Subsection 4.3.10 are based on a 460 mm projection.

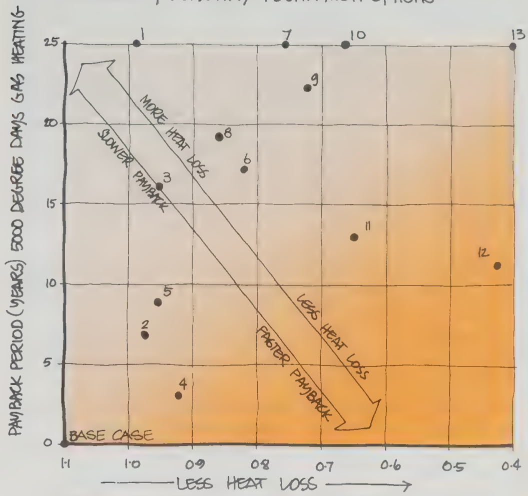
Where the house design favours a higher basement, such as with split-entry houses, the foundation itself should be terminated slightly above-grade and the wall continued with frame construction.

4.3.4 Insulation of Crawl Spaces

There are two basic approaches to the insulation of crawl spaces – either the floor above the crawl space can be insulated or the walls surrounding the crawl space and some portion of its floor can be insulated. The latter option is recommended since it provides a warm crawl space where ducts and piping can be routed without having to be insulated, and it generally provides a warmer floor. Also, there is usually less area to insulate with this approach. Some authorities may take the arbitrary view that unless heat is deliberately supplied to the crawl space it constitutes unheated space and therefore the floor separating it from the house must be insulated. Such a view can be countered

PAYBACK CHART A

CONCRETE & MASONRY FOUNDATION OPTIONS

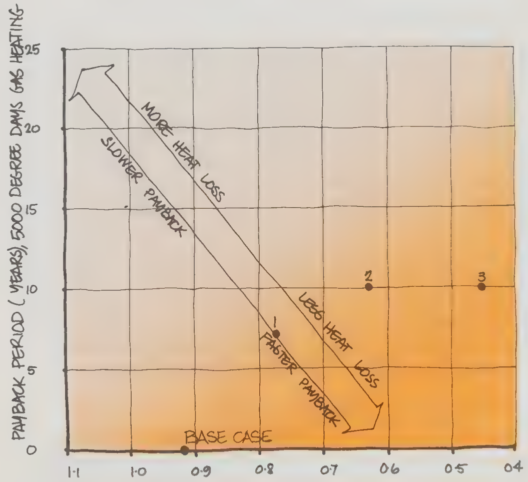


HEAT LOSS FACTOR— WATTS PER DEGREE CELSIUS PER METRE OF FOUNDATION PERIMETER – W/°C-m

NUMBERS INDICATE OPTIONS FROM TABLE 4·1

PAYBACK CHART B

PRESERVED WOOD FOUNDATION INSULATION OPTIONS



HEAT LOSS FACTOR W/°C-m

NUMBERS INDICATE OPTIONS FROM TABLE 4·2

by pointing out that the total heat loss from inside the house will not be increased by insulating the crawl space walls.

Vents with insulated, weatherstripped covers should be provided so that the crawl space can be ventilated in summer (Figure 4.14). Home buyers should be advised to open these for summer and close them in winter. Alternatively, if the crawl space is used as an insulated warm air plenum, the furnace fan can be left on in the summer to provide ventilation and vents will not be required.

The amount of insulation to use in a crawl space can be based on the options shown in Tables 4.1 and 4.2 for full basements. A thickness of insulation and a level below-grade judged economical for basements will also be economical for crawl spaces. There is the additional option that the portion which would have been placed below-grade can simply be laid along the floor of the crawl space (Figure 4.15). It should be noted, however that this method cuts off flow of heat to the footings and should only be used where the footings are below the frost line.

4.3.5 Insulating Slabs-on-Grade

Again the basement tables can be used as a guide to the amount of insulation and the depth below-grade. For example, if Option 9 in Table 4.1 were judged economic for a full basement wall, then applying 51 mm of extruded polystyrene to a depth of 1790 mm below-grade around the perimeter of a slab-on-grade would also be economic (Figure 4.16).

4.3.6 Wet Soils

The savings shown in Tables 4.1 and 4.2 following Subsection 4.3.10 are based on the assumption that the soil surrounding the foundation is not saturated with water and contributes to the thermal resistance between the air in the basement and the outside air. It has been found, however, that where the soil is very wet, and especially where there is water flowing through the soil, it not only fails to provide any insulation, but it can actually act as a heat drain. On wet sites, therefore, the savings from any given insulation option could be much larger than those shown in the tables – perhaps as much as 25% higher. The economic insulation level will therefore be correspondingly higher. Unfortunately, the current state of knowledge of below-grade heat losses does not permit more specific guidance here.

4.3.7 Insulating Basement Floors

At normal basement depths and where the soil is dry, there is already so much thermal resistance between the basement floor and the outside air that further insulation is unlikely to be worthwhile. It may be economic to insulate the floor of shallow basements and those on wet sites, however. For shallow basements follow the guide given for crawl spaces. For basements in wet soils, the entire basement floor should be insulated to the same R value as the basement walls.

4.3.8 Exterior-Applied Insulation

Applying insulation to the exterior of foundation walls offers the advantage of eliminating the need for any framing. Only a limited number of insulating materials is suitable for use in direct contact with the soil. Extruded polystyrene is the most commonly used. Although polystyrene beadboard has been used in this way, it

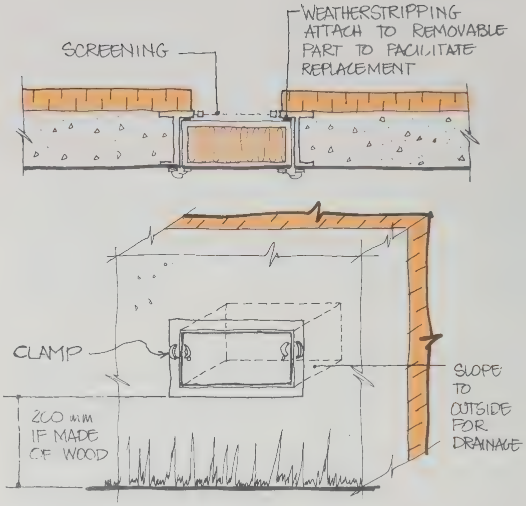


FIGURE 4·14 CRAWL SPACE VENTS AND COVERS

TOTAL VENT AREA = 1/500 OF CRAWL SPACE FLOOR AREA.

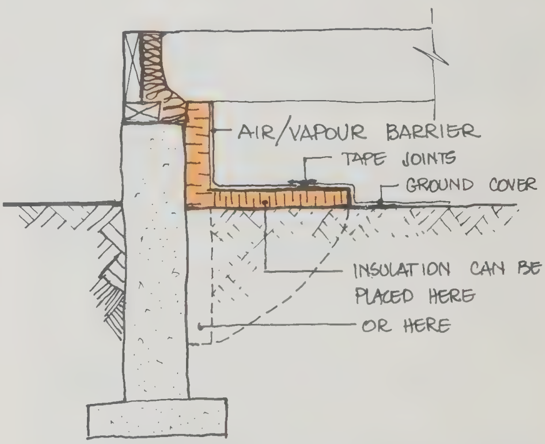


FIGURE 4·15 INSULATION OF CRAWL SPACES

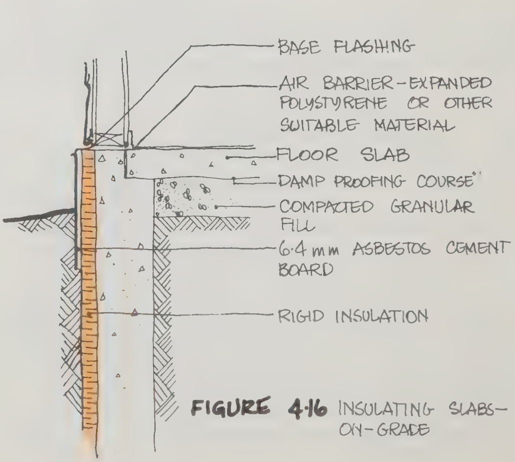


FIGURE 4·16 INSULATING SLABS-ON-GRADE

cannot be recommended with confidence because of its poor resistance to moisture. Type 1 expanded polystyrene, the lowest density type, is specifically precluded from this application in the National Building Code.

Recent studies by the National Research Council have shown encouraging but as yet incomplete results for a method of applying exterior insulation that has apparently been used with some success in Scandinavia. Rigid glass fibre insulation, similar to the type used on flat roofs, is applied to the full height of the foundation walls, where it acts as both insulation and a drainage layer permitting rapid drainage of any water in the soil down the face of the wall to the drainage tile.

The insulation must be protected above-grade from both mechanical damage and ultraviolet radiation. This can be accomplished by covering it with either 6.4 mm asbestos-cement board or with 12 mm cement parging applied to wire lath which is nailed through the insulation into the sill plate and foundation wall (Figure 4.17). A number of products on the market claim to provide a stucco-like finish over the insulation without the need for wire lath, but the performance of these products has not been uniformly good. The failure rate has been high enough to preclude any recommendation in favour of such products.

One method of applying insulation to the outside of foundations that is often recommended for insulating existing houses is to apply it down the foundation wall to just below grade and then outwards from the wall almost horizontally (Figure 4.18). This offers some advantage in a retrofit situation since it reduces the amount of excavation required, but in new construction the soil is excavated anyway. There have also been cases where this method was used on wet sites and proved to be completely ineffective since the heat flow is essentially horizontal and thus is not intercepted by horizontally placed insulation.

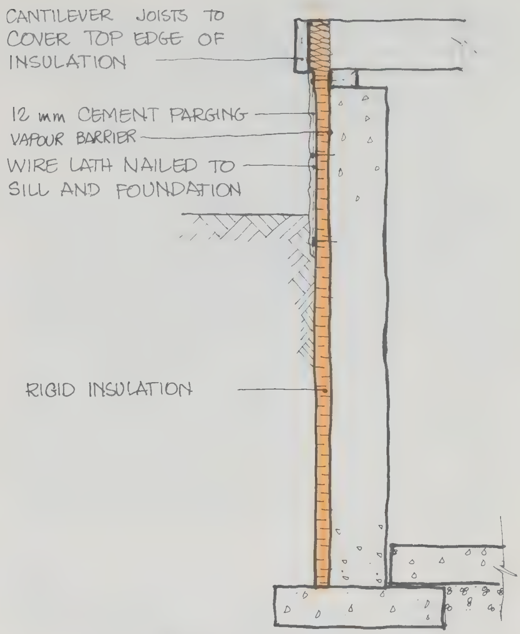


FIGURE 4·17 EXTERIOR APPLIED INSULATION

Note: For floor slab jointing details, see Figure 6–Perimeter Joint for Floor Slab–on page 17 of the HUDAC "Guide to Construction of Cast-in-Place Concrete Basements for Housing and Small Buildings".

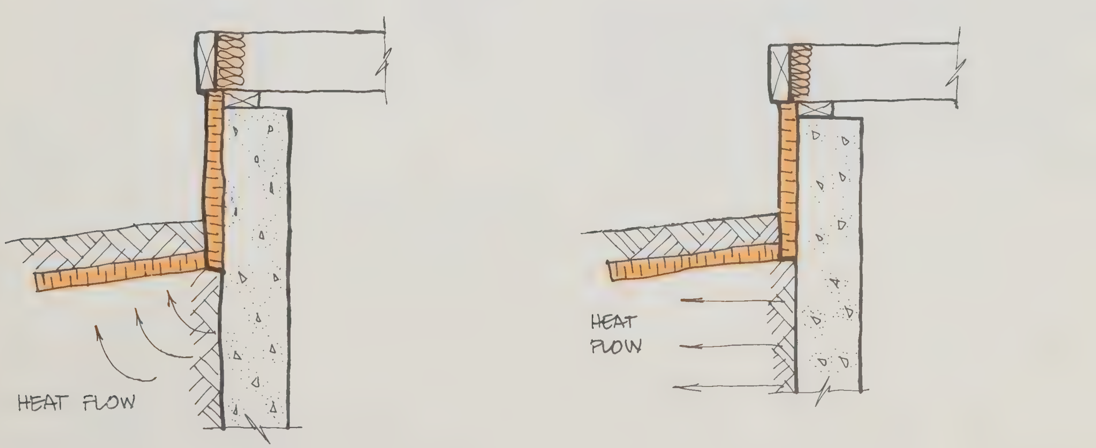


FIGURE 4·18 EFFECTIVENESS OF HORIZONTAL INSULATION

A DRY SOIL–HEAT FLOW IS INTERCEPTED BY HORIZONTAL INSULATION

B WET SOIL–HEAT FLOW IS NOT INTERCEPTED BY HORIZONTAL INSULATION

4.3.9 Interior-Applied Insulation

Applying insulation to the interior of foundation walls would seem straightforward enough until one realizes that the insulation must be protected in four ways –

- from condensation of interior humidity.
- from migration of exterior water through the wall.
- from fire
- from mechanical damage.

Working upwards from the bottom of this list, it should be realized that virtually all insulating materials are rather soft and easily damaged. They should be protected by a durable interior finishing material in any area where human activities take place. Cellular plastic insulation must, by code, be protected from fire. The concern here is not just that they are flammable but that they tend to contribute to the rapid spread of fire. This same concern applies to the asphalt-coated kraft paper vapour barrier commonly used on insulation batts, so these, too, require protection from fire. Where the finish is applied using adhesive, it should also be nailed or screwed at least at the top and bottom as additional protection in case the adhesive does not hold up in fire conditions.

Even the best basements are not completely watertight. There is always the risk of water migrating through the wall and affecting the insulation. The cellular plastics generally have enough moisture resistance that no further protection is required. Other types, and any wood applied to the inside of foundation walls, should be protected by dampproofing the inside surface of the wall. This can consist of bituminous coatings, polyethylene sheets or asphalt-impregnated felt building paper. This latter method is recommended since

a) building paper has high permeability and thus will not act as an additional vapour barrier, and

b) it has some limited ability to absorb and store water during periods of high flow, such as the spring, and then dissipate it slowly and harmlessly during dry periods.

The dampproofing should not be applied above the exterior grade level in order to facilitate dissipation of any moisture which does accumulate. Where wood is used in conjunction with cellular plastic, dampproofing of the whole wall just to protect the wood can be avoided by either wrapping or backing the wood members with polyethylene or using preservative treated wood.

Like any insulated building element, the foundation wall requires the protection of an effective air/vapour barrier. Insulation materials with low permeability, such as the cellular plastics, provide their own resistance to vapour diffusion and do not require an air/vapour barrier if the interior finish is applied so that its joints do not coincide with the insulation joints, and it fits tightly to the insulation. Otherwise the methods and principles illustrated in Subsection 4.1 generally apply. A few added precautions can be given (see also Figures 4.19 and 4.20):

- All edges of porous insulation should butt against solid blocking to discourage air circulation through the insulation.
- Place a bead of sealant beneath all strapping at the base of the insulation or caulk along the edge of the strapping against the wall to discourage air movement behind the insulation.
- Where rigid insulation is glued to the wall, apply the adhesive in a grid of beads rather than as daubs since then each bead acts as a further barrier to air movement. Where a protein-based adhesive is used it should be the type with preservative added to discourage the growth of fungi and other micro-organisms.

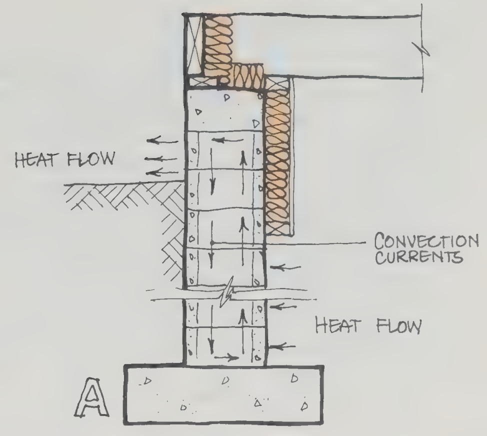
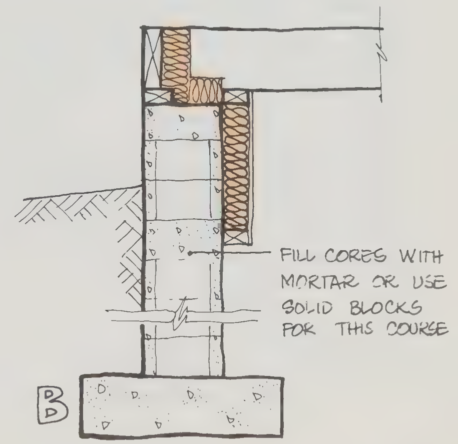


FIGURE 4.20 INSULATION OF HOLLOW MASONRY WALLS.

CONVECTION CURRENTS IN THE CORES OF HOLLOW MASONRY WALLS CAN GREATLY INCREASE HEAT LOSS. THIS EFFECT CAN BE REDUCED BY INSULATING FULL HEIGHT OR BY FILLING THE CORES EVEN WITH THE BOTTOM OF THE INSULATION.



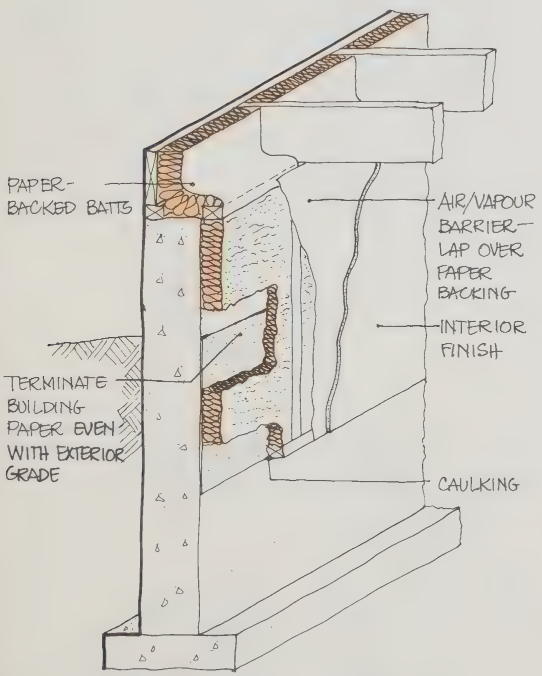


FIGURE 4.19 INTERIOR APPLIED INSULATION

4.3.10 Notes to Tables 4.1 and 4.2

1. Because the R value of the foundation wall is not uniform over the height a single R value for each option does not indicate its thermal effectiveness. Therefore an annual heat loss factor is given in addition to the R value of the above-grade portion. This factor expresses the amount of energy in watt-hours that will flow through a 1 metre wide vertical strip of wall, from subfloor to floor slab, in one hour with a one Celsius degree difference between inside and outside air temperatures. It includes heat loss through –
   – the joint header area
   – the above-grade portion of the foundation wall
   – the below-grade portion of the foundation wall.

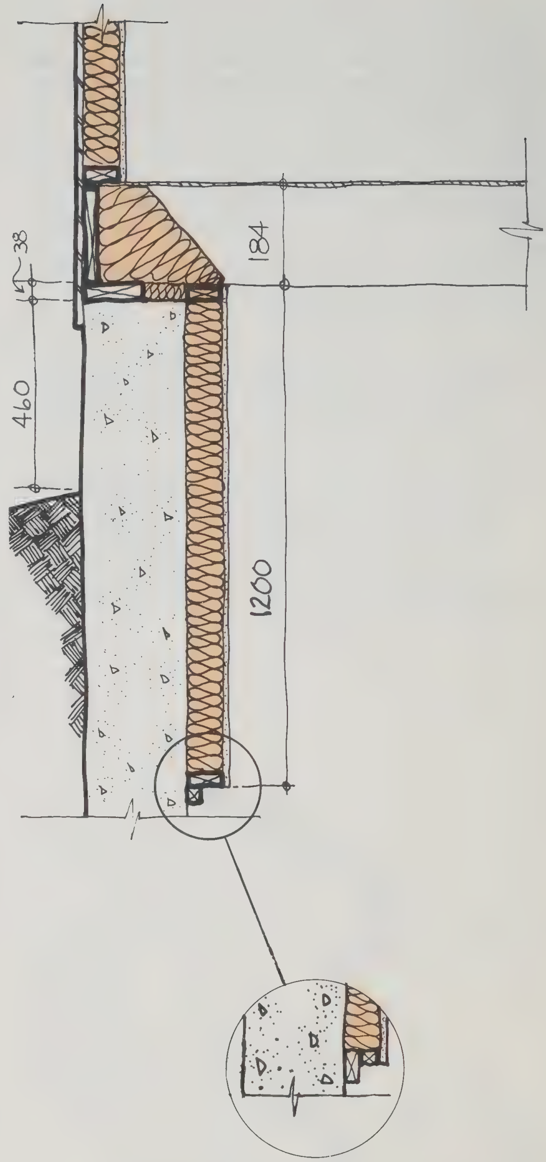
   The lower the heat loss factor, the more thermally effective the option.

2. All options are based on 200 mm thick foundation walls 2250 mm high, projecting 460 mm above the exterior grade and supporting 38 mm thick sill plates and 184 mm deep joists. The options with insulation only part way down the wall are detailed as shown opposite.

3. Some of the insulation options in Table 4.1 involve building a 38 x 64 stud wall in front of the foundation wall and spacing it out from the foundation wall in order to accommodate batts thicker than 64 mm. Where this is done, full width batts (sometimes referred to as 'steel stud batts') should be used so that they will fill in the spaces behind the studs.

4. The Guide recommends a) damp proofing on outside of foundation wall from footing to grade level, b) damp proofing on inside of foundation wall from bottom of insulation to a height equivalent to grade level, and c) vapour barrier between insulation and gypsum board.

Symbols: P.B. – paper-backed
F.F. – friction fit
H.L.F. – annual heat loss factor.

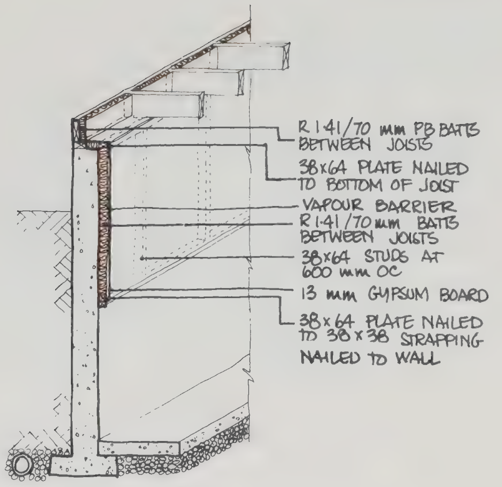


ALTERNATE DETAIL
REQUIRES COMPRESSION OF INSULATION

Table 4.1 Concrete & Masonry Foundation Insulation Options

BASE CASE
R above grade = 1.73
H.L.F. = 1.095 W/°C–m

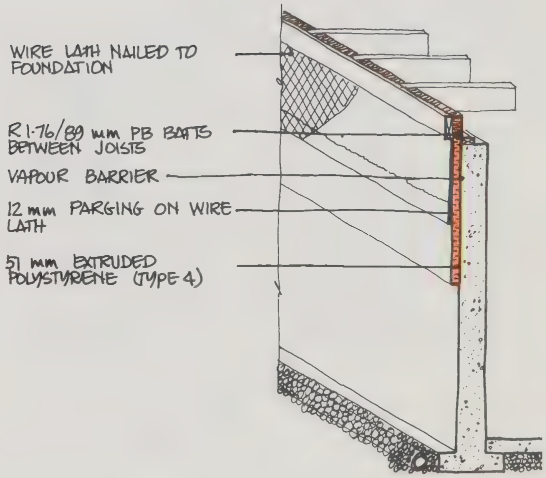
The following options are arranged in ascending order of R value.



Partial Depth Insulation Options

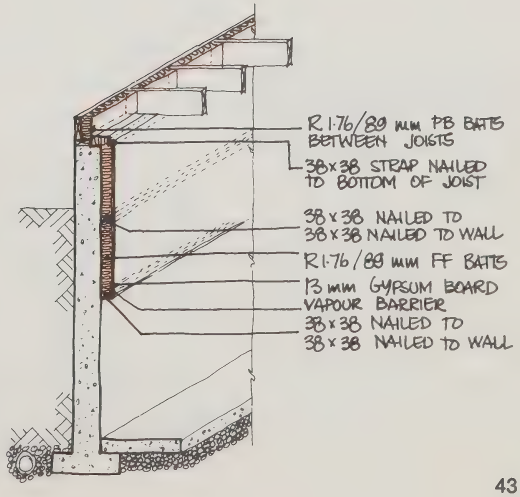
OPTION 1
R above grade = 2.02
Estimated cost premium $237
H.L.F. = 0.981 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$6.97 25+	$5.75 25+	$9.58 25+
5000	Est. Annual Saving Payback (years)	$8.66 25+	$7.20 25+	$11.95 25+
6000	Est. Annual Saving Payback (years)	$10.42 23	$8.66 25+	$14.32 20



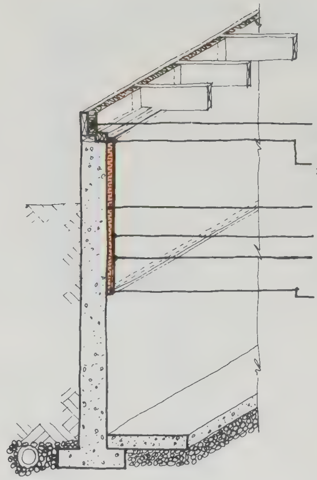
OPTION 2
R above grade = 2.08
Estimated cost premium $54
H.L.F. = 0.975 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.28 8	$6.05 9	$10.03 6
5000	Est. Annual Saving Payback (years)	$9.12 6	$7.58 7	$12.56 5
6000	Est. Annual Saving Payback (years)	$10.95 5	$9.12 6	$15.09 4



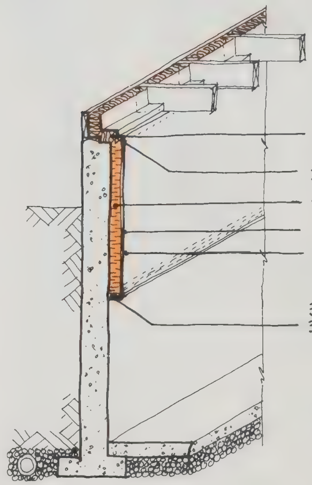
OPTION 3
R above grade = 2.23
Estimated cost premium $138
H.L.F. = 0.956 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$8.43 17	$7.05 20	$11.64 14
5000	Est. Annual Saving Payback (years)	$10.57 14	$8.81 16	$14.55 11
6000	Est. Annual Saving Payback (years)	$12.72 11	$10.57 14	$17.46 9



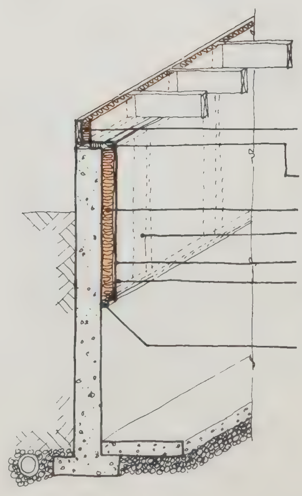
OPTION 4
R above grade = 2.27
Estimated cost premium $31
H.L.F. = 0.924 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$10.42 3	$8.66 4	$14.32 2
5000	Est. Annual Saving Payback (years)	$13.02 3	$10.80 3	$17.85 2
6000	Est. Annual Saving Payback (years)	$15.63 2	$13.02 3	$21.45 2



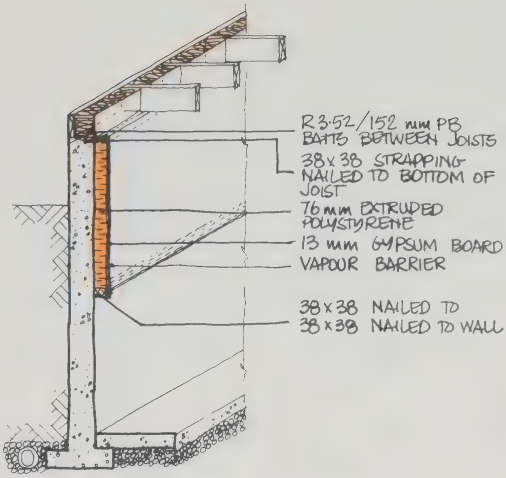
OPTION 5
R above grade = 2.43
Estimated cost premium $77
H.L.F. = 0.957 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$8.43 10	$6.97 12	$11.57 8
5000	Est. Annual Saving Payback (years)	$10.49 8	$8.73 9	$14.40 6
6000	Est. Annual Saving Payback (years)	$12.56 7	$10.49 8	$17.31 5



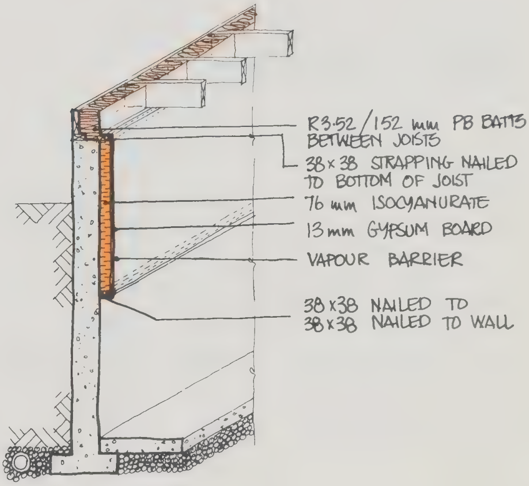
OPTION 6
R above grade = 2.95
Estimated cost premium $299
H.L.F. = 0.817 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$16.93 18	$14.09 21	$23.29 15
5000	Est. Annual Saving Payback (years)	$21.14 14	$17.62 17	$29.11 12
6000	Est. Annual Saving Payback (years)	$25.35 12	$21.14 14	$34.85 10



OPTION 7
R above grade = 4.15
Estimated cost premium $575
H.L.F. = 0.752 W/°C–m

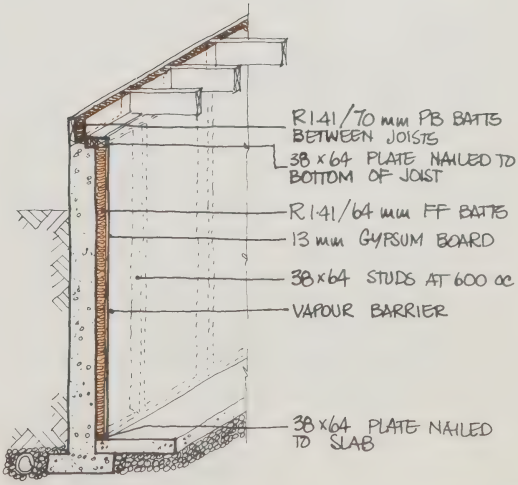
C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$20.84 25 +	$17.39 25 +	$28.73 25+
5000	Est. Annual Saving Payback (years)	$26.04 22	$21.75 25 +	$35.85 19
6000	Est. Annual Saving Payback (years)	$31.25 19	$26.04 22	$43.05 16



Full Depth Insulation Options

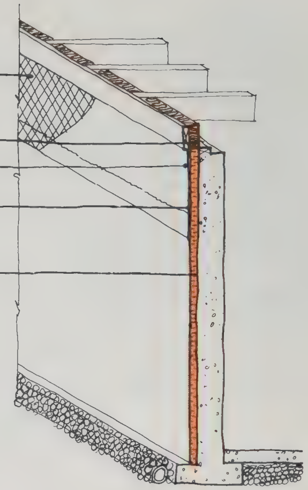
OPTION 8
R above grade = 1.73
Estimated cost premium $283
H.L.F. = 0.855 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$14.63 19	$12.18 23	$20.07 16
5000	Est. Annual Saving Payback (years)	$18.23 16	$15.17 19	$25.12 13
6000	Est. Annual Saving Payback (years)	$21.91 13	$18.23 16	$30.10 11



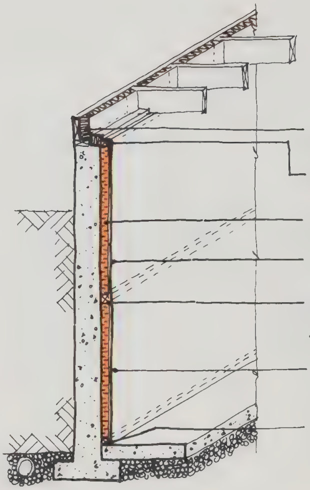
OPTION 9
R above grade = 2.02
Estimated cost premium $521
H.L.F. = 0.721 W/°C–m

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$22.75 23	$18.92 25+	$31.25 20
5000	Est. Annual Saving Payback (years)	$28.42 18	$23.67 22	$39.14 15
6000	Est. Annual Saving Payback (years)	$34.09 15	$28.42 18	$46.96 13



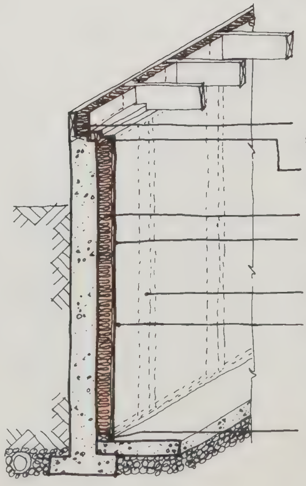
OPTION 10
R above grade = 2.23
Estimated cost premium $712
H.L.F. = 0.659 W/°C–m

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$26.50 25+	$22.06 25+	$36.46 24
5000	Est. Annual Saving Payback (years)	$33.17 21	$27.65 25+	$45.58 19
6000	Est. Annual Saving Payback (years)	$39.76 18	$33.17 21	$54.69 15



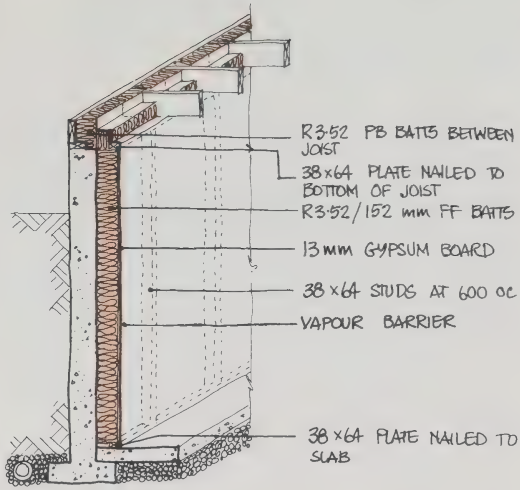
OPTION 11
R above grade = 2.43
Estimated cost premium $345
H.L.F. = 0.658 W/°C–m

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$26.58 13	$22.14 16	$36.54 11
5000	Est. Annual Saving Payback (years)	$33.24 11	$27.65 13	$45.73 8
6000	Est. Annual Saving Payback (years)	$39.83 9	$33.24 11	$54.85 7



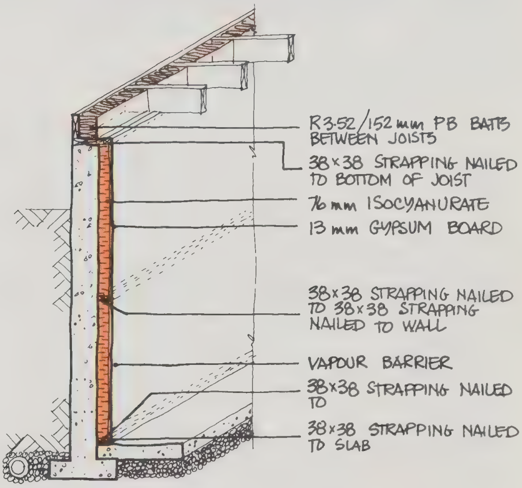
OPTION 12
R above grade = 3.84
Estimated cost premium $460
H.L.F. = 0.423 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$40.83 12	$34.09 14	$56.22 9
5000	Est. Annual Saving Payback (years)	$51.09 9	$42.59 11	$70.24 7
6000	Est. Annual Saving Payback (years)	$61.28 8	$51.09 9	$84.34 6



OPTION 13
R above grade = 4.15
Estimated cost premium $1417
H.L.F. = 0.402 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$42.13 25+	$35.08 25+	$57.99 25+
5000	Est. Annual Saving Payback (years)	$52.70 25+	$43.89 25+	$72.46 24
6000	Est. Annual Saving Payback (years)	$63.20 22	$52.70 25+	$86.94 19

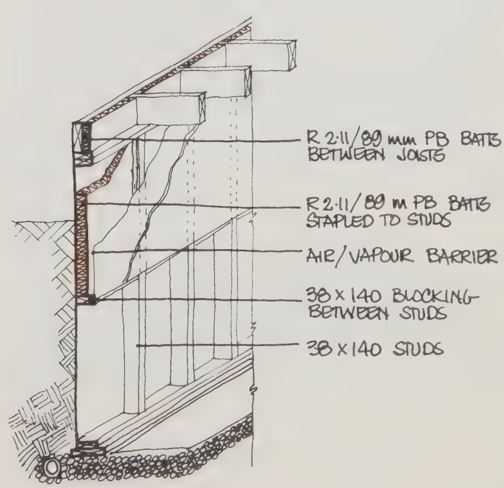


OPTION 13

Table 4.2 Preserved Wood Foundation Insulation Options

BASE CASE
R above grade = 2.45
H.L.F. = 0.920 W/°C–m

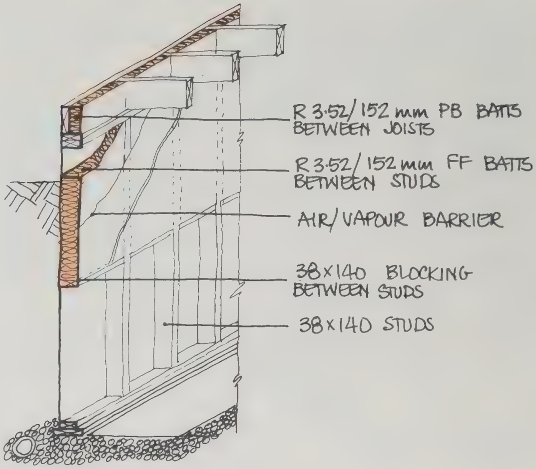
The following options are arranged in ascending order of R value.



Partial Depth Insulation Options

OPTION 1
R above grade = 3.06
Estimated cost premium $54
H.L.F. = 0.787 W/°C–m

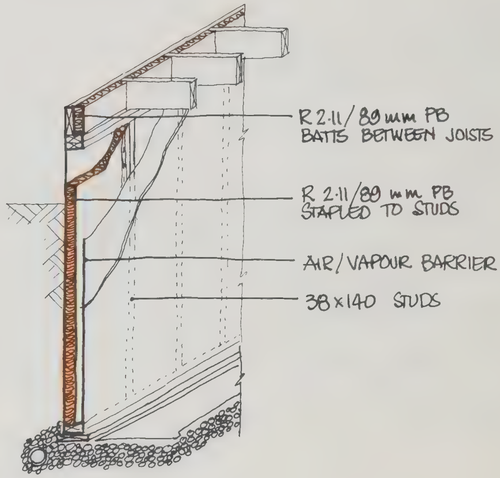
C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$8.12 7	$6.75 8	$11.11 5
5000	Est. Annual Saving Payback (years)	$10.11 6	$8.43 7	$13.94 4
6000	Est. Annual Saving Payback (years)	$12.10 5	$10.11 6	$16.70 4



Full Depth Insulation Options

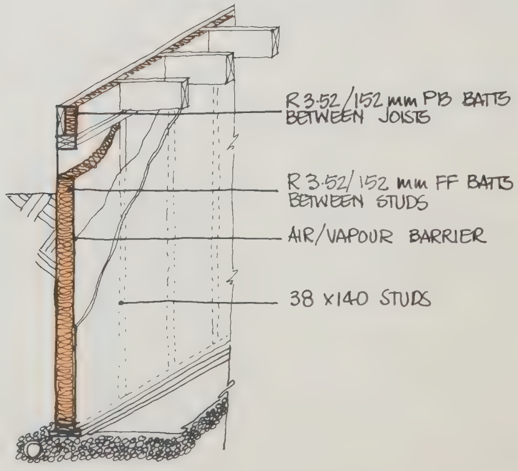
OPTION 2
R above grade = 2.45
Estimated cost premium $176
H.L.F. = 0.640 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$17.01 11	$14.17 13	$23.44 9
5000	Est. Annual Saving Payback (years)	$21.29 9	$17.77 10	$29.26 7
6000	Est. Annual Saving Payback (years)	$25.51 7	$21.29 9	$35.16 6



OPTION 3
R above grade = 3.86
Estimated cost premium $268
H.L.F. = 0.457 W/°C–m

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$28.19 10	$23.44 12	$38.76 8
5000	Est. Annual Saving Payback (years)	$35.16 8	$29.34 10	$48.41 6
6000	Est. Annual Saving Payback (years)	$42.21 7	$35.16 8	$58.14 5



4.4 Floors

Floors separating heated space from unheated space or the outdoors must be insulated. This condition commonly occurs over unheated garages and crawl spaces and at floor overhangs.

4.4.1 Recommendations

- Insulate floors above garages even if the garage is intended to be heated.
- Use insulation to the full thickness of the joists in floors.
- Apply sheathing and sheathing paper on floor overhangs with great care in order to achieve an effective air barrier.

See Payback Chart C for summary analysis of options.

4.4.2 General Notes

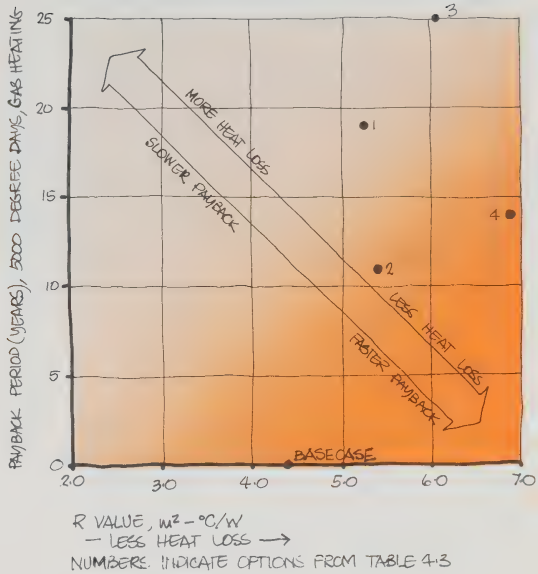
Even where a garage is provided with heating facilities it is a good idea to insulate the construction separating it from the house since garages are often left open for extended periods, and even where heating facilities are provided they are often not used. This is not specifically required by the Ontario Building Code but is prescribed in CMHC Builders' Bulletin No. 267.

The added cost of using insulation to the full thickness of the joists in floors (compared to the 152 mm batts permitted by the Ontario Building Code) theoretically has a relatively long payback period (Table 4.3). But the total added cost is quite small unless the house has an unusually high amount of insulated floor, and it is strongly recommended because it greatly facilitates the proper insulation of the floor perimeter.

Failure to insulate the floor perimeter properly and to provide an effective air barrier that prevents circulation of cold outside air through the floor space are common causes of complaints about cold floors. Full thickness insulation combined with the air barrier practices shown in Figure 4.21 will go far towards eliminating these problems. Another defence against cold floors is to ensure, through proper design of the heating system, that heated air is circulated across the floor (see Section 5).

PAYBACK CHART C

FLOOR INSULATION OPTIONS



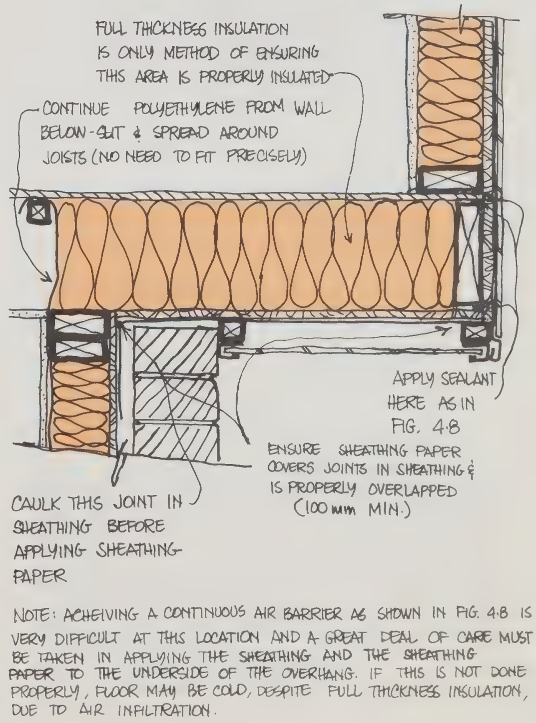


FIGURE 4·21 TREATMENT OF FLOOR OVERHANG

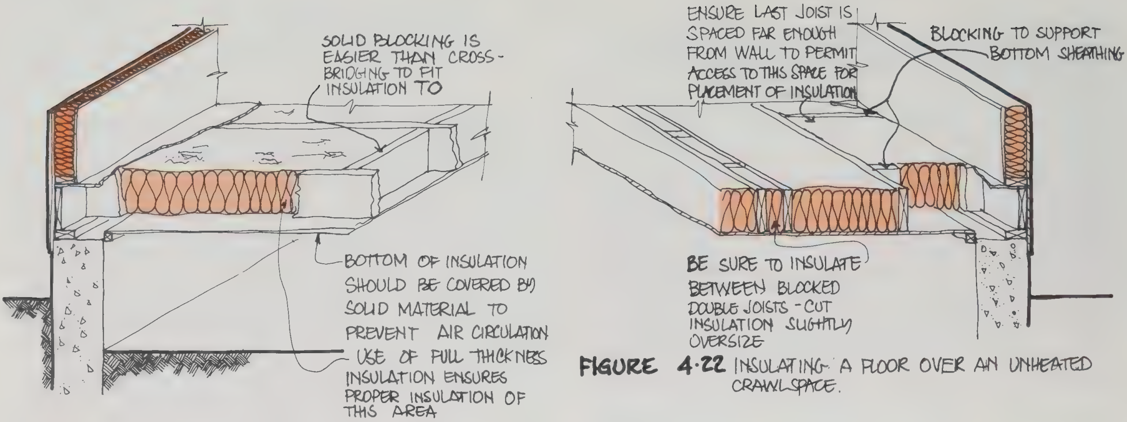
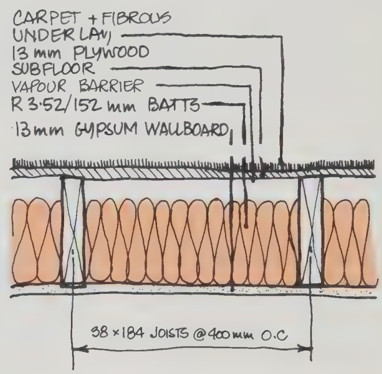


FIGURE 4·22 INSULATING A FLOOR OVER AN UNHEATED CRAWLSPACE.

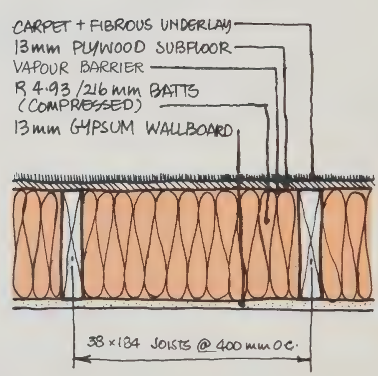
Table 4.3 Floor Insulation Options

BASE CASE
R = 4.45 m² °C/W



The following options are arranged in ascending order of R value.

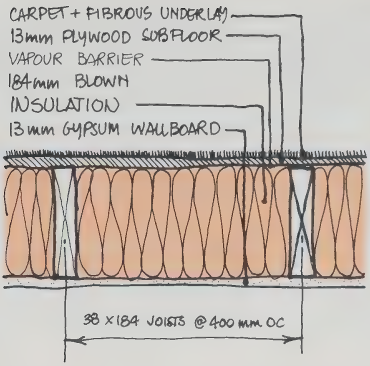
OPTION 1
R = 5.25 m² °C/W
Estimated cost premium $21



C Degree Days		Type of Heating: Oil	Gas	Elect.
4000	Est. Annual Saving	$1.12	$0.94	$1.54
	Payback (years)	19	23	16
5000	Est. Annual Saving	$1.40	$1.18	$1.82
	Payback (years)	16	19	13
6000	Est. Annual Saving	$1.68	$1.96	$1.94
	Payback (years)	13	16	11

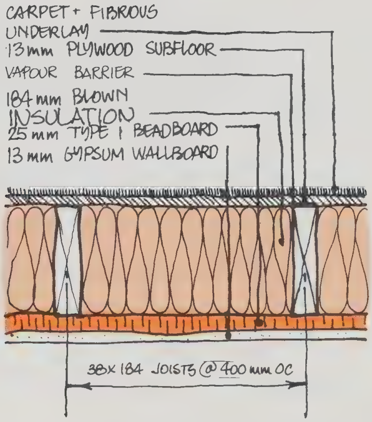
OPTION 2
R = 5.41 m² °C/W
Estimated cost premium $14

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$1.30 11	$1.08 13	$1.80 9
5000	Est. Annual Saving Payback (years)	$1.62 9	$1.36 11	$2.24 7
6000	Est. Annual Saving Payback (years)	$1.96 8	$1.62 9	$2.68 6



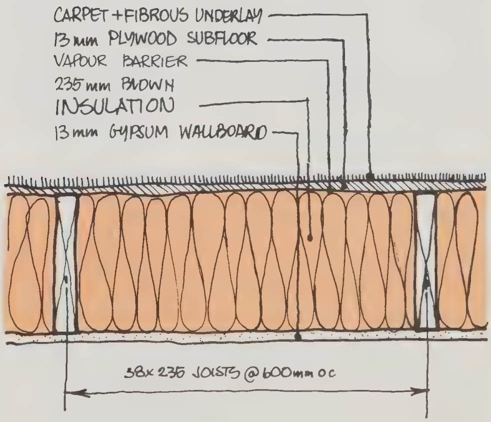
OPTION 3
R = 6.06 m² °C/W
Estimated cost premium $59

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$2.30 25+	$1.92 25+	$3.16 23
5000	Est. Annual Saving Payback (years)	$2.88 21	$2.40 25+	$3.94 18
6000	Est. Annual Saving Payback (years)	$3.44 17	$2.88 21	$4.74 15



OPTION 4
R = 6.69 m² °C/W
Estimated cost premium $43

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$2.94 15	$2.44 18	$4.04 12
5000	Est. Annual Saving Payback (years)	$3.68 12	$3.06 14	$5.04 10
6000	Est. Annual Saving Payback (years)	$4.40 10	$3.66 12	$6.06 8



4.5 Walls

The Ontario Building Code prescribes the use of R 2.11 insulation in walls. Until recently this was the highest R value batt available for use in 38 x 89 stud walls. CMHC Builders' Bulletin No. 267 accomplishes much of the same effect by prescribing an overall R value of 2.5 which can be achieved by combining R 2.11 batts with common cladding, sheathing and finish materials. However the proposed 'Measures for Energy Conservation in New Buildings' prescribes higher R values for much of the country than can be achieved with normal 38 x 89 stud walls, and many builders are already building with higher R value walls. The following notes review various ways of achieving such higher R values.

4.5.1 Recommendations

- In choosing a method of achieving higher R values for walls, the builder should be guided not only by payback but also by the compatibility of the method and materials with his construction process.
- Use the widest framing spacing permissible in order to reduce the thermal bridging effect.
- Use corner and intersection details which reduce the amount of framing and allow it to be replaced by insulation.

See Payback Chart D for summary analysis of options.

There are basically three methods of achieving higher R values with wood-frame walls:
- higher density insulation batts
- deeper studs
- rigid insulation in place of sheathing.

No one method is right for all builders since each has its particular advantages.

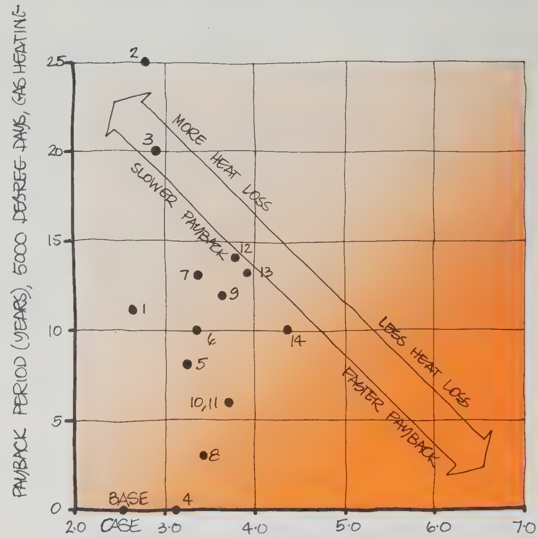
4.5.2 Higher Density Insulation Batts

R 2.47/89 mm batts suitable for installation in 38 x 89 stud walls have recently been made available. Although these batts are expensive (costing almost twice as much as R 2.11/89 mm batts or more than R 3.52/152 mm batts) they have the significant advantage of providing an extra R 0.36 with no other change in construction practices. Of course the maximum overall R value that can be achieved with this method is limited to about R 2.9 unless these batts are used in combination with a rigid insulation in place of conventional sheathing.

4.5.3 Deeper Studs

The use of 38 x 140 studs permits the installation of R 3.52/152 mm batts although the resulting compression of the batts reduces their R value to 3.36. Table 4.5 following Subsection 4.5.5 indicates that this method is fairly cost effective when used with no sheathing (Option 10). Historically, however, few builders have chosen to omit sheathing entirely even though it has been permitted by codes for several years. (Omission of the sheathing behind ventilated claddings can lead to increased air leakage due to wind displacing the sheathing paper). Another consideration is that the supply of 38 x 140 lumber is limited, especially in Eastern Canada. If this method became popular, the cost of such lumber could increase and alter the economics.

PAYBACK CHART D
WALL INSULATION OPTIONS



R VALUE, m2 - °C/W
— LESS HEAT LOSS ⟶
NUMBERS INDICATE OPTIONS FROM TABLE 4.4

4.5.4 Rigid Insulation in Place of Sheathing

Although the commonly used sheathing materials such as plywood, wafer board or gypsum board all contribute to the total insulation value, their contribution is relatively small. Since building codes don't require the use of sheathing, it is possible to omit it, and use instead a rigid insulation that is continuous over the outer faces of the studs. But most rigid insulation materials are not as strong as conventional sheathing materials, and may not withstand the rugged handling associated with platform frame construction, especially when the walls are prefabricated. Also, sidings must be nailed through the rigid insulation into the framing. Care is required to avoid waviness in the siding due to uneven compression of the insulation.

Where it can be used, however, this method has an important advantage: its thermal resistance is continuous over the framing, reducing heat loss and achieving a more uniform R value over the whole wall. A wide variety of rigid insulation materials is available. The most common ones are listed in Table 4.4 along with their advantages and disadvantages. These considerations combined with the economic analysis results in Table 4.5 following Subsection 4.5.5 should assist in the choice of the most suitable rigid material and thickness to use.

4.5.5 Other Factors

One consideration that applies to methods in Subsections 4.5.3 and 4.5.4, is that both increase the thickness of the wall to some degree. This obviously entails some extra cost for such things as

- longer roof trusses
- more siding
- deeper window and door frames
  or
- reduced floor area

The extra cost is difficult to measure, but is likely to be small. No allowance was made for this factor in the cost estimates in Table 4.5. However, builders may want to keep this in mind when weighing the relative merits of these methods.

The costs in Table 4.5 are all based on 600 mm stud spacing, whether the studs are 38 x 89 or 38 x 140, even though builders have traditionally used 400 mm spacing. Where 400 mm spacing of 38 x 89 studs is required, such as for the first storey wall of a 2-storey house, the relative economics of the 38 x 140 stud options will be enhanced. The use of 600 mm spacing is recommended, where permitted, since it results in an appreciable increase in the overall thermal resistance of a wall (4% to 8%).

Choice of the proper framing details at corners and intersections can also reduce the amount of wood in the wall and increase the amount of insulation. Suggested details are shown in Figure 4.23.

Table 4.4 Rigid Insulation Materials

Rigid Insulation	Advantages	Disadvantages
Fibre Board	– strongest – best backing for siding	– lowest R value – highest cost per R
Type 1 Expanded Polystyrene (Beadboard)	– lowest cost per R	– least strength and rigidity
Phenolic Foam Board	– fairly rigid due to paper facings – high permeability*	– relatively high cost
Extruded Polystyrene	– high strength – high R value	– low permeability* – relatively high cost
Foil-Faced Isocyanurate Foam Board	– highest R value – fairly rigid due to foil facings	– lowest permeability*
Semi-Rigid Glass Fibre Board	– high permeability* – may enhance air-tightness by fitting snugly to plates, headers etc.	– easily crushed

*Note: There is some risk of condensation problems arising from the placement of low permeability materials on the outside of walls. However no documented cases of such problems have come to light and use of the air/vapour barrier installation practices shown in Subsection 4.1 should minimize any such risk.

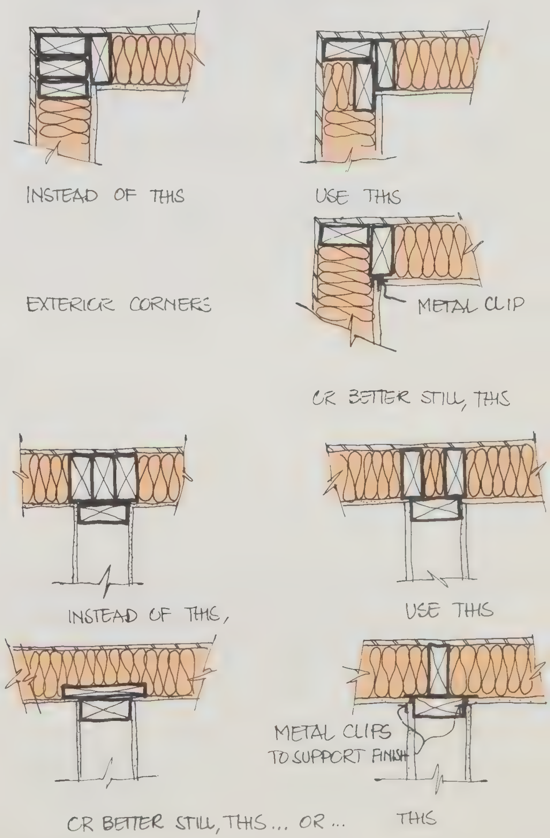
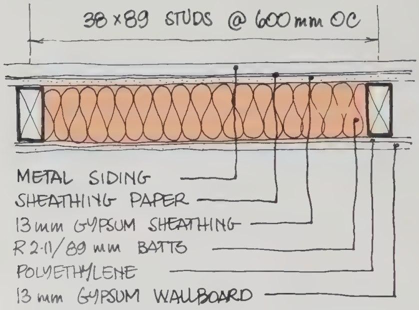


FIGURE 4·23
INTERSECTION AND CORNER DETAILS

Table 4.5 Wall Insulation Options

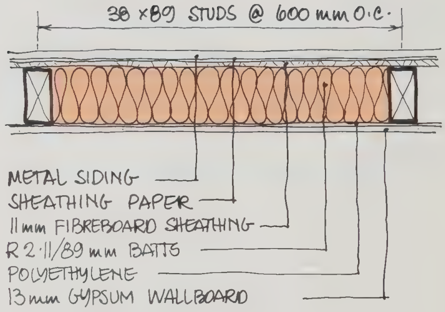
BASE CASE
R = 2.56 m² °C/W

The following options are arranged in ascending order of R value.



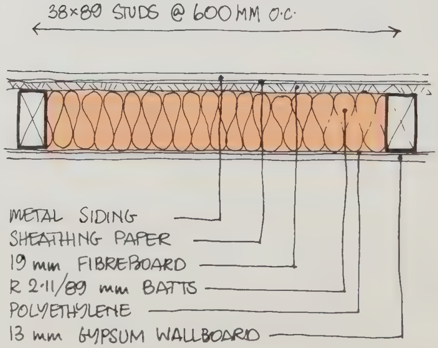
OPTION 1
R = 2.66 m² °C/W
Estimated cost premium $56

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$5.25 11	$4.40 13	$7.10 9
5000	Est. Annual Saving Payback (years)	$6.53 9	$5.40 11	$8.95 7
6000	Est. Annual Saving Payback (years)	$7.81 8	$6.53 9	$10.79 6



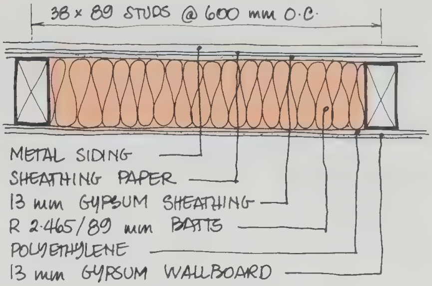
OPTION 2
R = 2.79 m² °C/W
Estimated cost premium $271

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$9.09 25+	$7.53 25+	$12.50 25+
5000	Est. Annual Saving Payback (years)	$11.36 24	$9.51 25+	$15.62 21
6000	Est. Annual Saving Payback (years)	$13.63 20	$11.36 24	$18.74 17



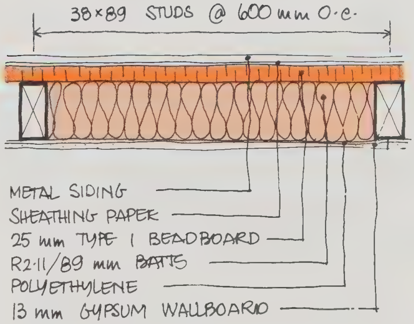
OPTION 3
R = 2.91 m² °C/W
Estimated cost premium $222

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$10.79 21	$8.95 25	$14.77 18
5000	Est. Annual Saving Payback (years)	$13.49 17	$11.22 20	$18.46 14
6000	Est. Annual Saving Payback (years)	$16.19 14	$13.49 17	$22.15 11



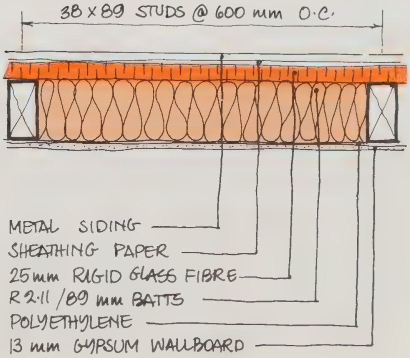
OPTION 4
R = 3.12 m² °C/W
Estimated cost premium $0

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$23.86 0	$19.88 0	$32.30 0
5000	Est. Annual Saving Payback (years)	$29.82 0	$24.85 0	$41.04 0
6000	Est. Annual Saving Payback (years)	$35.78 0	$29.82 0	$49.27 0



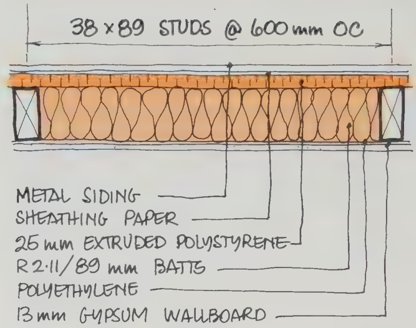
OPTION 5
R = 3.25 m² °C/W
Estimated cost premium $221

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$27.69 8	$23.15 10	$38.06 7
5000	Est. Annual Saving Payback (years)	$34.65 7	$23.83 8	$47.57 5
6000	Est. Annual Saving Payback (years)	$41.61 6	$34.65 7	$57.08 5



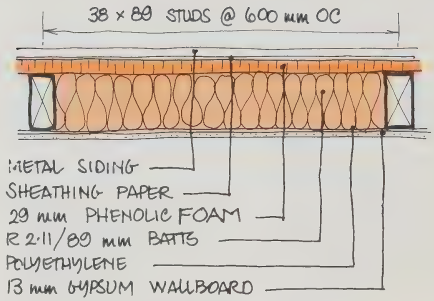
OPTION 6
R = 3.36 m² °C/W
Estimated cost premium $312

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$30.67 11	$25.56 13	$42.17 8
5000	Est. Annual Saving Payback (years)	$38.34 9	$31.95 10	$52.82 7
6000	Est. Annual Saving Payback (years)	$46.01 7	$38.34 9	$63.33 6



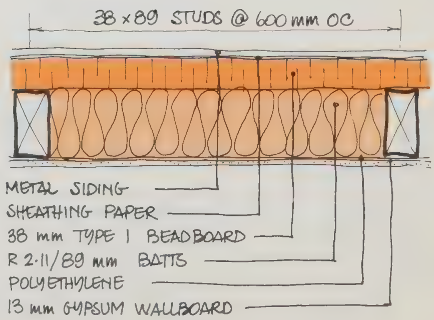
OPTION 7
R = 3.36 m² °C/W
Estimated cost premium $415

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$30.67 14	$25.56 16	$42.17 11
5000	Est. Annual Saving Payback (years)	$38.34 11	$31.95 13	$52.82 9
6000	Est. Annual Saving Payback (years)	$46.01 9	$38.34 11	$63.33 7



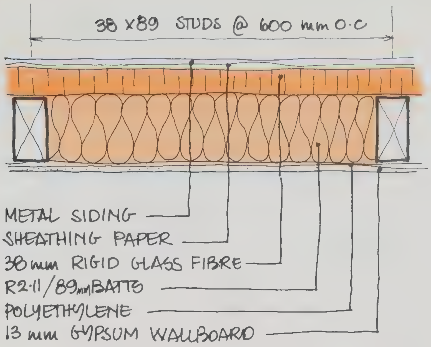
OPTION 8
R = 3.45 m² °C/W
Estimated cost premium $85

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$33.23 3	$27.69 4	$45.72 2
5000	Est. Annual Saving Payback (years)	$41.61 3	$34.65 3	$57.23 2
6000	Est. Annual Saving Payback (years)	$49.84 2	$41.61 3	$68.59 2



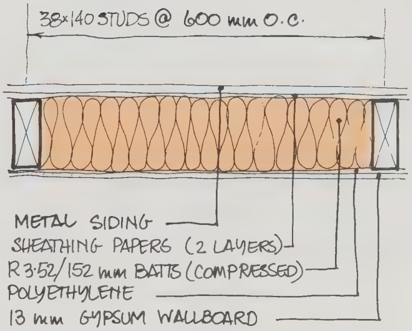
OPTION 9
R = 3.66 m² °C/W
Estimated cost premium $452

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$38.06 12	$31.81 15	$52.40 10
5000	Est. Annual Saving Payback (years)	$47.71 10	$39.76 12	$65.60 8
6000	Est. Annual Saving Payback (years)	$57.23 8	$47.57 10	$78.67 7



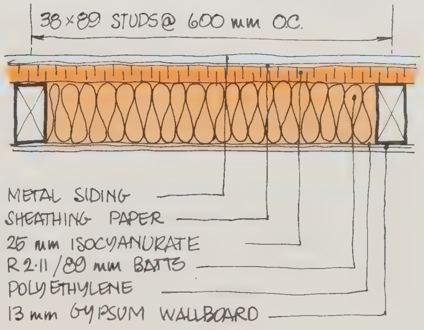
OPTION 10
R = 3.74 m² °C/W
Estimated cost premium $204

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$33.80 7	$28.12 8	$46.43 5
5000	Est. Annual Saving Payback (years)	$42.17 5	$35.07 6	$58.08 4
6000	Est. Annual Saving Payback (years)	$50.55 5	$42.17 5	$69.58 4



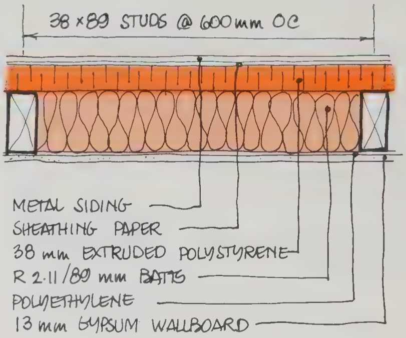
OPTION 11
R = 3.75 m² °C/W
Estimated cost premium $237

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$39.76 6	$33.23 8	$54.81 5
5000	Est. Annual Saving Payback (years)	$49.70 5	$41.46 6	$68.44 4
6000	Est. Annual Saving Payback (years)	$59.78 4	$49.70 5	$82.22 3



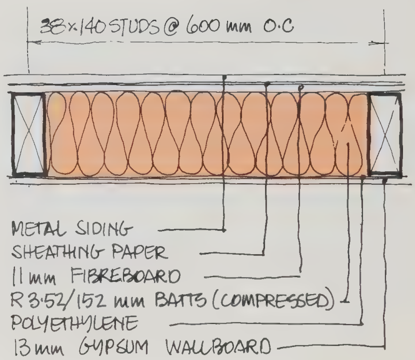
OPTION 12
R = 3.80 m² °C/W
Estimated cost premium $595

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$41.04 15	$34.22 13	$56.52 12
5000	Est. Annual Saving Payback (years)	$51.26 12	$42.74 14	$70.57 10
6000	Est. Annual Saving Payback (years)	$61.63 10	$51.26 12	$84.63 8



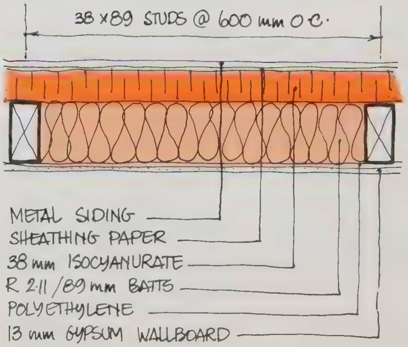
OPTION 13
R = 3.91 m² °C/W
Estimated cost premium $515

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$38.06 14	$31.81 16	$52.40 11
5000	Est. Annual Saving Payback (years)	$47.71 11	$39.76 13	$65.60 9
6000	Est. Annual Saving Payback (years)	$57.23 9	$47.57 11	$78.67 7



OPTION 14
R = 4.38 m² °C/W
Estimated cost premium $493

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$51.40 10	$42.74 12	$70.72 8
5000	Est. Annual Saving Payback (years)	$64.18 8	$53.53 10	$88.32 6
6000	Est. Annual Saving Payback (years)	$77.11 7	$64.13 8	$106.07 5



4.6 Attic-type Roofs

Builders can make attic-type roofs more energy efficient simply by increasing the amount of insulation. Additional care must be taken to ensure proper ventilation.

4.6.1 Recommendations

- Order loose fill insulation by weight rather than thickness.
- Increase ceiling gypsumboard thickness when thick water-based texture finishes are used.
- Insulate the ceiling before any moisture producing operations are undertaken during winter construction.
- Ventilate houses during winter construction to carry away the moisture produced by construction processes and the use of gas-fired heaters.
- Keep soffit vents open.
- Use baffles to prevent insulation from being displaced or penetrated by wind.

See Payback Chart E for summary analysis of options.

4.6.2 Insulation and Application Factors

Technically there is no mystery to achieving higher R values with attic-type roofs. It's simply a matter of piling in more insulation – either batts or loose fill or some combination of the two. The figures in Table 4.7 following Subsection 4.6.3 should provide guidance in the choice of type and amount. For simplicity, only the words, 'blown insulation', have been used and can be considered indicative of the general economics of loose fill insulation.

Certain types of loose fill insulation, including cellulose fibre and mineral wool, are subject to settling after installation if they are not installed properly. For this reason it is best to specify such materials by weight rather than by thickness. For example, CMHC requires that cellulose fibre manufacturers print a table such as Table 4.6 on their bags.

These figures can be found in CMHC's 'Acceptable Building Materials System and Equipment Manual' for all accepted cellulose fibre insulation. Comparable data for mineral wool insulation can also be found. Based on the above, it would be necessary to install 78 kg of material to achieve an R value of 5.0 over a 10 m² ceiling. Its final settled thickness would be 202 mm but it might be 242 mm thick or more immediately after installation. This would not matter as long as 78 kg or more were ordered and installed.

There has been some concern expressed in recent years that the added weight of the insulation levels now being considered can lead to sagging of gypsumboard ceilings. Although this is not entirely without basis, recent studies have indicated that the problem is caused principally by dampening of the gypsumboard due to some combination of the following conditions:

- application of thick, water-based, textured finishes

PAYBACK CHART E

ATTIC TYPE ROOF INSULATION OPTIONS

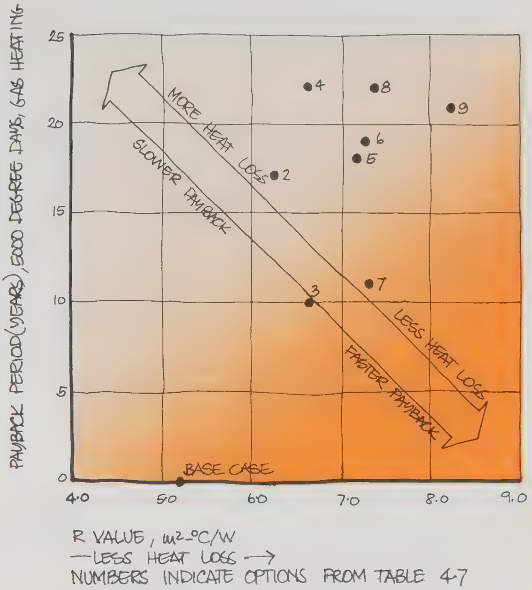


Table 4.6 Thermal Resistance by Thickness and Weight of Cellulose Fibre

Thermal Resistance RSI	Thickness (On Day of Application) mm	Settled mm	Weight per Unit Area Kg/Sq M
1.0	(46)	39	1.5
2.0	(93)	78	3.0
3.0	(142)	119	4.6
4.0	(193)	161	6.2
5.0	(242)	202	7.8
6.0	(291)	243	9.3
7.0	(340)	284	10.9

(The values in this table are not necessarily typical since they will vary from one manufacturer to another.)

- high humidity during winter construction due to rapid drying of building materials in tightly closed houses
- vapour diffusing through the board and condensing on the vapour barrier prior to installation of the insulation during winter construction.

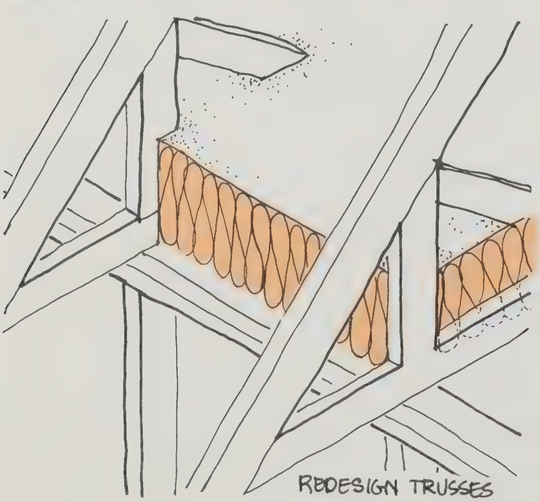
If any of the above conditions cause the board to sag, it will sag even more with added insulation on it. The primary way of avoiding this problem is not to decrease the amount of insulation but to use stronger gypsumboard (16 mm instead of 13 mm) or avoid the above conditions by:

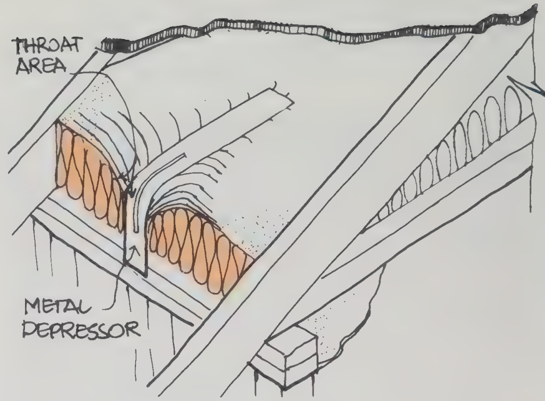
- not using thick, water-based, textured finishes
- providing better ventilation during construction
- installing insulation before undertaking moisture-producing operations such as pouring the basement floor slab or applying water-based finishes.

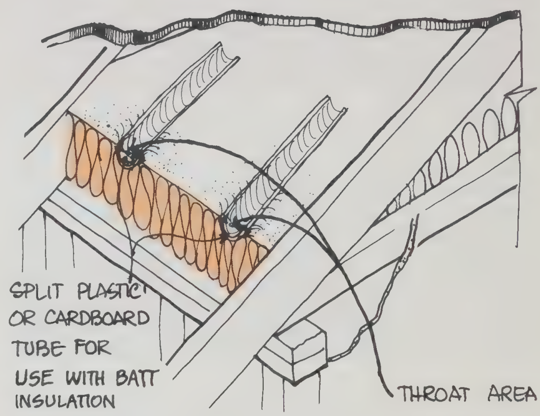
4.6.3 Ventilation of Attic-type Roofs

Roof space ventilation is the second line of defence against attic condensation problems (the first being the creation of a good ceiling air/vapour barrier). It is easily accomplished in attic-type roofs. The vent area specified by codes is normally adequate (1/300 of ceiling area for most roofs, 1/150 of ceiling area for low slope roofs). It should be distributed evenly around the building. When practical, half of the vent area should be located in the soffits and the other half high on the roof (gable, roof or ridge vents) in order to take advantage of stack effect created by solar heating of the attic. The construction of low and high vents may also help in summer cooling. The only precaution that requires mention is the need to avoid rendering soffit vents useless by blocking the area between the wall top plate and the roof sheathing with insulation. A number of methods of avoiding this are shown in Figure 4.24 and 4.25.

For a further discussion of roof space ventilation see Subsection 4.7.2







NOTE: TOTAL THROAT AREA SHOULD AT LEAST EQUAL TOTAL SOFFIT VENT AREA.

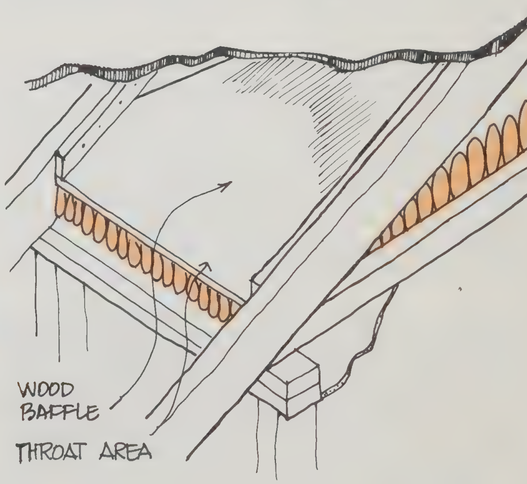


FIGURE 4·24 VARIOUS METHODS OF AVOIDING RESTRICTION OF ROOF SPACE VENTILATION WITH DEEP INSULATION.

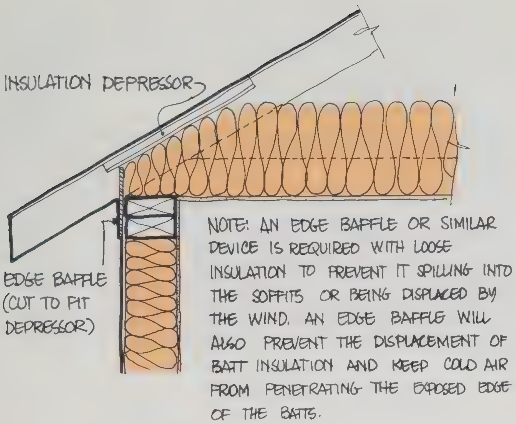
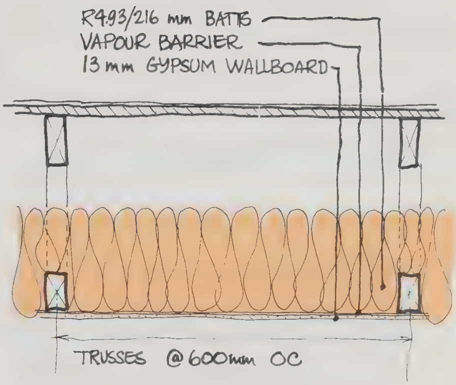


FIGURE 4.25 EDGE BAFFLE

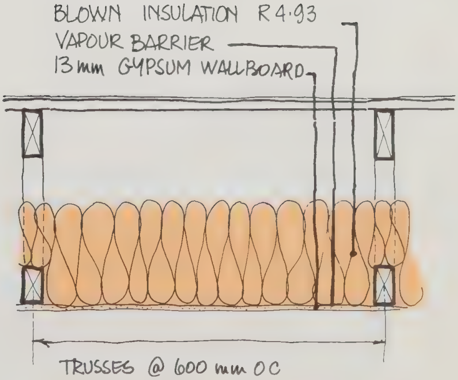
Table 4.7 Attic Type Roof Insulation Options

BASE CASE
R = 5.16 m² °C/W



The following options are arranged in ascending order of R value.

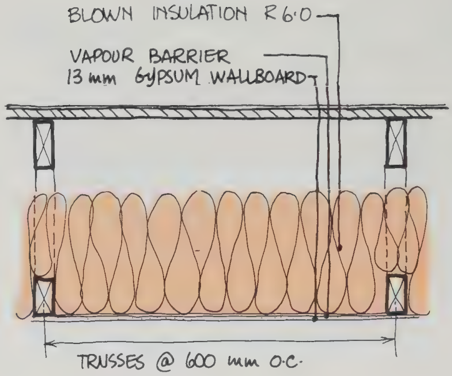
OPTION 1
R = 5.16 m² °C/W
Estimated cost premium $0



C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$0.00 0	$0.00 0	$0.00 0
5000	Est. Annual Saving Payback (years)	$0.00 0	$0.00 0	$0.00 0
6000	Est. Annual Saving Payback (years)	$0.00 0	$0.00 0	$0.00 0

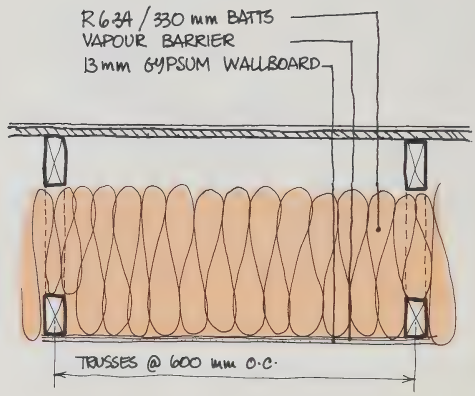
OPTION 2
R = 6.23 m² °C/W
Estimated cost premium $77

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving	$4.34	$3.64	$5.95
	Payback (years)	17	21	14
5000	Est. Annual Saving	$5.39	$4.48	$7.42
	Payback (years)	14	17	11
6000	Est. Annual Saving	$6.51	$5.39	$8.96
	Payback (years)	12	14	9



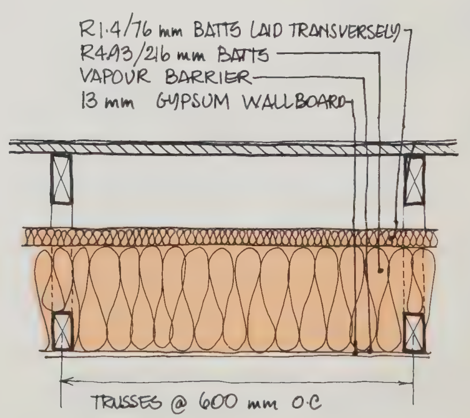
OPTION 3
R = 6.57 m² °C/W
Estimated cost premium $56

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving	$5.46	$4.55	$7.49
	Payback (years)	11	13	8
5000	Est. Annual Saving	$6.86	$5.67	$9.38
	Payback (years)	9	10	7
6000	Est. Annual Saving	$8.19	$6.79	$11.27
	Payback (years)	7	9	6



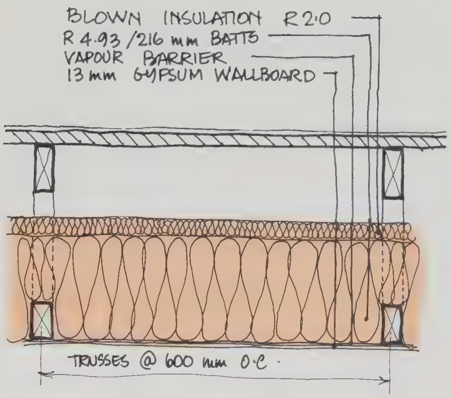
OPTION 4
R = 6.57 m² °C/W
Estimated cost premium $126

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving	$5.46	$4.55	$7.49
	Payback (years)	23	25 +	20
5000	Est. Annual Saving	$6.86	$5.67	$9.38
	Payback (years)	18	22	15
6000	Est. Annual Saving	$8.19	$6.79	$11.27
	Payback (years)	15	18	13



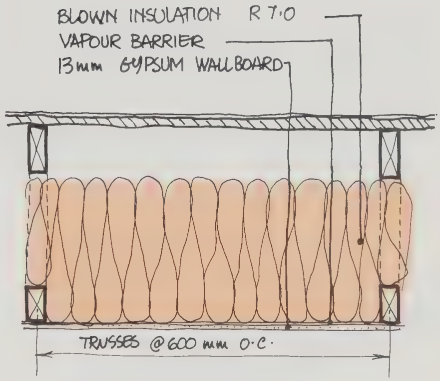
OPTION 5
R = 7.16 m² °C/W
Estimated cost premium $133

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.14 19	$5.95 22	$9.80 16
5000	Est. Annual Saving Payback (years)	$8.89 15	$7.42 18	$12.25 12
6000	Est. Annual Saving Payback (years)	$10.71 13	$8.89 15	$14.70 10



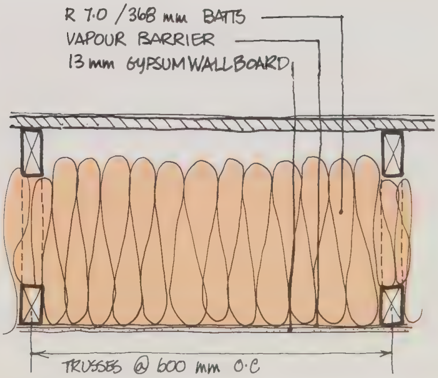
OPTION 6
R = 7.23 m² °C/W
Estimated cost premium $147

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.28 20	$6.02 24	$10.01 17
5000	Est. Annual Saving Payback (years)	$9.10 16	$7.56 19	$12.46 13
6000	Est. Annual Saving Payback (years)	$10.92 14	$9.10 16	$14.98 11



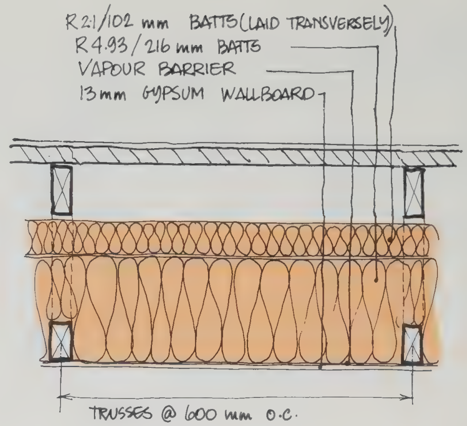
OPTION 7
R = 7.27 m² °C/W
Estimated cost premium $84

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.42 11	$6.16 13	$10.22 9
5000	Est. Annual Saving Payback (years)	$9.24 9	$7.70 11	$13.74 7
6000	Est. Annual Saving Payback (years)	$11.13 8	$9.24 9	$15.33 6



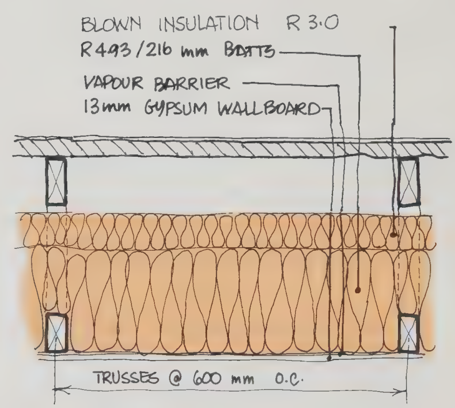
OPTION 8
R = 7.27 m² °C/W
Estimated cost premium $175

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.42 23	$6.16 25 +	$10.22 20
5000	Est. Annual Saving Payback (years)	$9.24 19	$7.70 22	$12.74 16
6000	Est. Annual Saving Payback (years)	$11.13 16	$9.24 19	$15.33 13



OPTION 9
R = 8.16 m² °C/W
Estimated cost premium $203

C Degree Days		Type of Heating Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$9.38 22	$7.84 25 +	$12.88 19
5000	Est. Annual Saving Payback (years)	$11.69 17	$9.73 21	$16.10 15
6000	Est. Annual Saving Payback (years)	$14.07 15	$11.69 17	$19.32 12



4.7 Flat and Cathedral Roofs

Insulating this type of roof is much more difficult, the problem being to accommodate the required thickness of insulation and still leave enough room for ventilation between the insulation and the roof deck.

4.7.1 Recommendations

- Avoid the use of flat and cathedral roofs if possible.
- Where a flat or cathedral roof is required, use truss framing if possible.

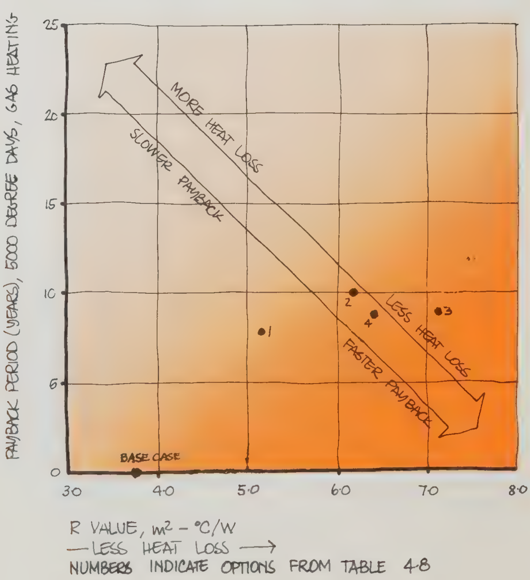
See Payback Charts F and G for summary analysis of options.

4.7.2 Ventilation

In Subsection 4.6 it was stated that ventilation of the roof space is not as important as a good air/vapour barrier in preventing condensation problems. But since it is probably impossible to create a perfect air/vapour barrier, ventilation should not be overlooked.

The role of roof space ventilation is not fully understood

PAYBACK CHART F
FLAT & CATHEDRAL ROOF INSULATION OPTIONS
-TRUSS FRAMING



at this time, even by building scientists. It is commonly believed that its main purpose is to dissipate water vapour entering the roof space through imperfections in the air/vapour barrier. How effective cold winter air (which is already at 80% or 90% relative humidity) would be in performing this function is subject to doubt.

It may be that the most important function of roof space ventilation is the drying out of winter condensation by the warmer spring and summer air. There are probably thousands of houses in Canada which experience some mild buildup of condensation in the roof space over the winter without any problems, due to the provision of adequate ventilation. Without such ventilation, the moisture can remain in the roof space into the summer, when the combination of high temperature and moisture creates ideal conditions for the growth of decay organisms.

Achieving adequate ventilation in a joist roof space that is filled or nearly filled with insulation is extremely difficult. Although not all such roofs suffer from wood decay and other condensation problems, it occurs often enough that most codes (including the Ontario Building Code and CMHC Builder's Bulletin No. 258) have requirements which virtually rule out this type of construction.

4.7.3 Methods of Insulation

There are three methods of insulating flat and cathedral type roofs –

- Use deep joists and cross-purlins to create a ventilation space above the insulation.
- Use parallel chord trusses to create a ventilation space above the insulation.
- Use rigid insulation applied on top of the roof sheathing.

The advantages and disadvantages of these methods are discussed below:

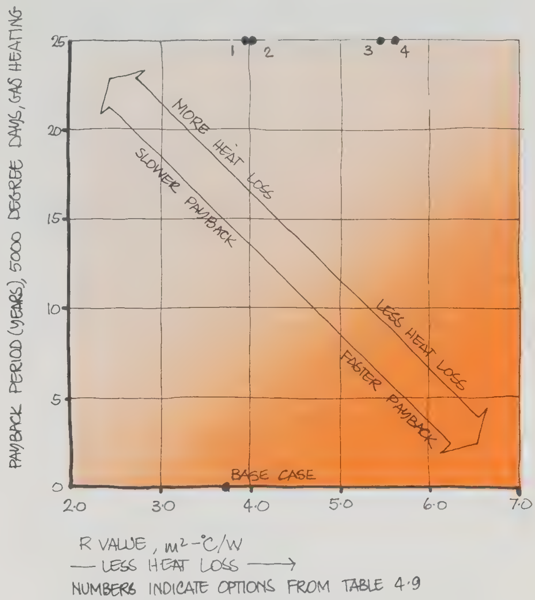
Cross-purlins

The Ontario Building Code requires a minimum of 152 mm clearance between the top of the insulation and the underside of the roof sheathing. To provide this clearance with the required amount of insulation for this type of roof (R.3.52) when 152 mm batts are used requires at least 38 x 235 joists combined with 38 x 89 cross-purlins. This is expensive unless the span requires 38 x 235 joists in any case. However, it has the advantage of using familiar materials and carpentry.

Parallel Chord and Scissor Trusses

The use of parallel chord trusses (either flat or sloping) may be a more economical method of increasing the depth of the roof. The open nature of trusses also allows cross-ventilation between truss spaces, which is desirable since moisture escaping through an imperfection in the air/vapour barrier can be dissipated over a wider area. In order to be economical, however, trusses require a significantly greater depth than joists for the same span, and this will not always have an acceptable appearance. For cathedral ceilings, scissors trusses rather than parallel chord trusses may be used (Figure 4.26).

PAYBACK CHART G
FLAT & CATHEDRAL ROOF INSULATION OPTIONS
–JOIST FRAMING



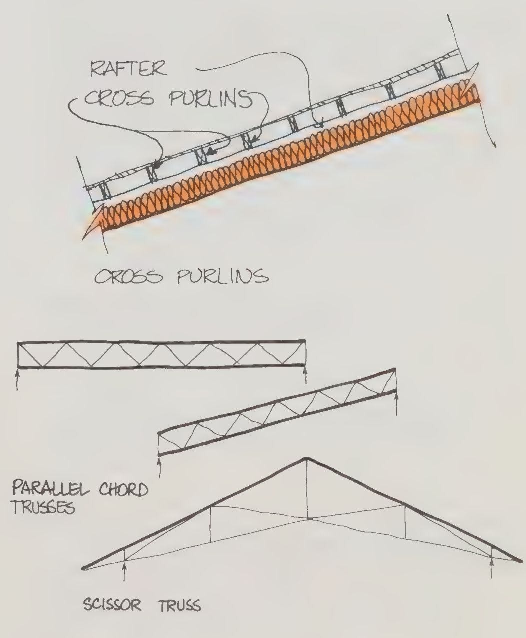


FIGURE 4.26 ROOF TYPES

Rigid Insulation
Placing the insulation on top of the roof sheathing eliminates a cold cavity within the roof and thus greatly reduces the risk of condensation. But, rigid insulation materials are generally expensive and may have to be put on in multiple layers to achieve even the minimum Ontario Building Code R value. A variation of this method is the so-called 'upside down roof' (Options 3 and 4 in Table 4.8 following Subsection 4.7.4) in which the roofing membrane is placed directly on the roof sheathing and the insulation is placed on top of it, rather than the other way around. This has the advantage of protecting the membrane from ultraviolet radiation and large temperature variations. However, good drainage is essential to avoid floating the insulation and the weight of the added ballast must be taken into account in the structural design of the roof. Only insulations which are highly resistant to water can be used for this method. CMHC will accept only extruded polystyrene.

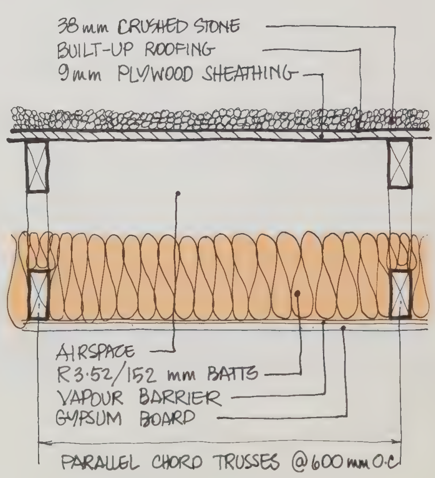
4.7.4 Cost Comparisons
Cross purlins and rigid insulation involving the use of joist framing appear to be at least 15% more expensive than the truss method, but this doesn't include a number of costs associated with the extra depth of a truss roof – additional siding, shingles and sheathing, for instance. Such costs vary according to the design of the individual house. Another factor that must be considered is the 'aesthetic cost', the appearance of the thicker roof. Thus a simple cost comparison between joists and truss roof options is not valid, and so the two have been put into separate tables (4.8 and 4.9 following this subsection) with different base cases.

Within the joist framing options, Table 4.9 indicates that only the cross-purlin method (the base case) is economic, since all the others have payback periods in excess of 25 years. This reflects the big difference in cost per unit of R value between batt and rigid insulation. However, the R Value of the cross-purlin option cannot be increased without intruding into the 152 mm clearance required above the insulation. In order to comply with requirements more stringent than the Ontario Building Code, such as CMHC Builder's Bulletin No. 267, it would be necessary to use one of the rigid insulation options or truss framing.

Table 4.8 Flat & Cathedral Roof Insulation Options – Truss Framing

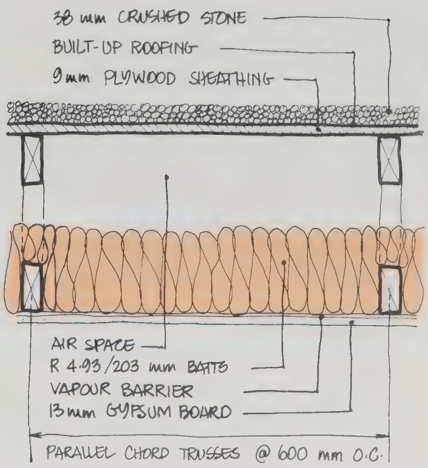
BASE CASE
R = 3.74 m² °C/W

The following options are arranged in ascending order of R value.



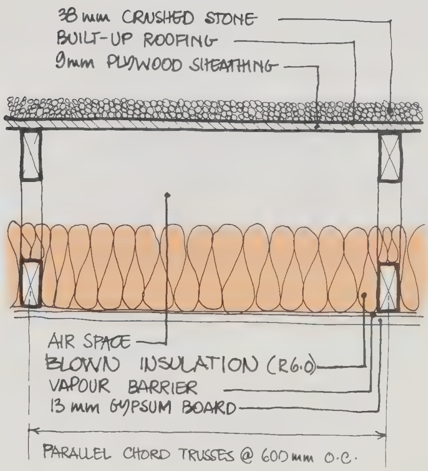
OPTION 1
R = 5.15 m² °C/W
Estimated cost premium $84

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$9.94 9	$8.26 10	$13.65 7
5000	Est. Annual Saving Payback (years)	$12.39 7	$10.36 8	$17.08 5
6000	Est. Annual Saving Payback (years)	$14.91 6	$12.39 7	$20.51 5



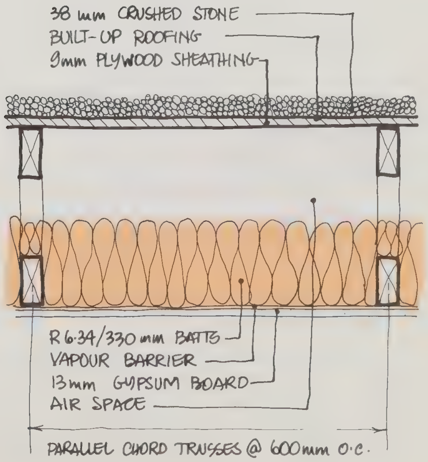
OPTION 2
R = 6.22 m² °C/W
Estimated cost premium $154

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$14.28 11	$11.90 13	$19.60 9
5000	Est. Annual Saving Payback (years)	$17.85 9	$14.84 10	$24.57 7
6000	Est. Annual Saving Payback (years)	$21.42 7	$17.85 9	$29.47 6



OPTION 3
R = 6.56 m² °C/W
Estimated cost premium $133

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$15.54 9	$12.95 11	$21.42 7
5000	Est. Annual Saving Payback (years)	$19.46 7	$16.17 9	$26.74 6
6000	Est. Annual Saving Payback (years)	$23.31 6	$19.46 7	$32.06 5



OPTION 4
R = 7.22 m² °C/W
Estimated cost premium $161

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$17.36 9	$14.42 11	$23.87 7
5000	Est. Annual Saving Payback (years)	$21.63 8	$18.06 9	$29.82 6
6000	Est. Annual Saving Payback (years)	$25.97 7	$21.63 8	$35.77 5

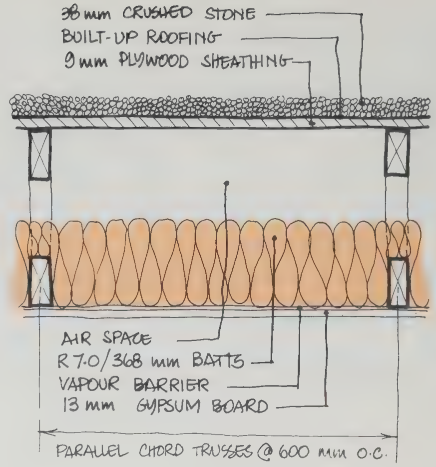
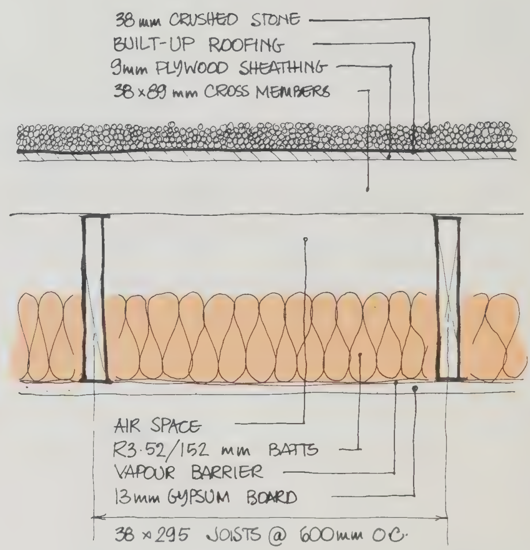


Table 4.9 Flat & Cathedral Roof Insulation Options – Joist Framing

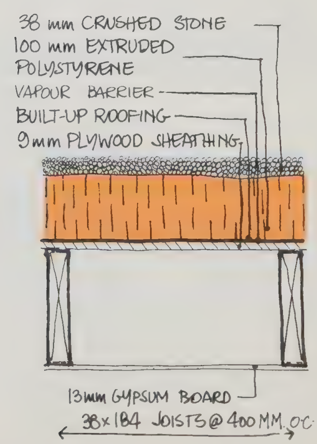
BASE CASE
R = 3.74 m² °C/W



The following options are arranged in ascending order of R value.

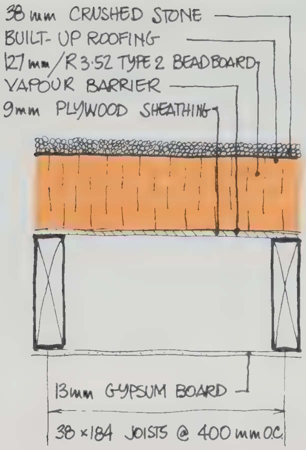
OPTION 1
R = 4.00 m² °C/W
Estimated cost premium $535

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.21 25 +	$6.02 25 +	$9.94 25 +
5000	Est. Annual Saving Payback (years)	$9.03 25 +	$7.49 25 +	$12.39 25 +
6000	Est. Annual Saving Payback (years)	$10.78 25 +	$9.03 25 +	$14.91 25 +



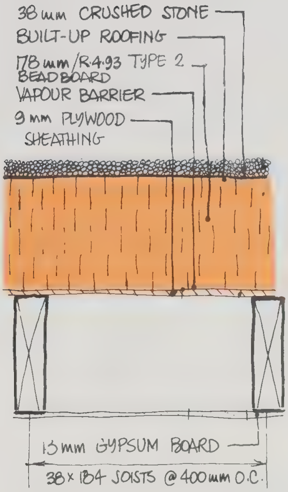
OPTION 2
R = 4.05 m² °C/W
Estimated cost premium $385

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$7.63 25 +	$6.30 25 +	$10.43 25 +
5000	Est. Annual Saving Payback (years)	$9.52 25 +	$7.91 25 +	$13.09 25 +
6000	Est. Annual Saving Payback (years)	$11.41 25 +	$9.52 25 +	$15.68 25 +



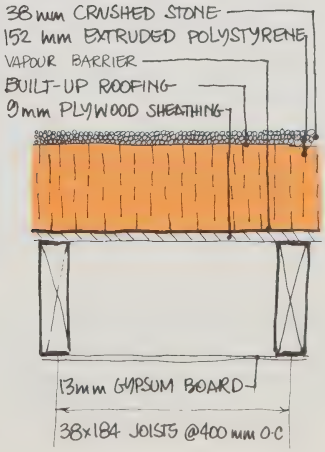
OPTION 3
R = 5.46 m² °C/W
Estimated cost premium $756

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$15.68 25 +	$13.09 25 +	$21.63 25 +
5000	Est. Annual Saving Payback (years)	$19.60 25 +	$16.38 25 +	$27.02 25 +
6000	Est. Annual Saving Payback (years)	$23.52 25 +	$19.60 25 +	$32.41 25 +



OPTION 4
R = 5.61 m² °C/W
Estimated cost premium $1057

C Degree Days		Type of Heating		
		Oil	Gas	Elect.
4000	Est. Annual Saving Payback (years)	$16.31 25 +	$13.58 25 +	$22.47 25 +
5000	Est. Annual Saving Payback (years)	$20.37 25 +	$17.01 25 +	$28.07 25 +
6000	Est. Annual Saving Payback (years)	$24.50 25 +	$20.37 25 +	$33.67 25 +



4.8 Windows

General opinions on windows have varied sharply in recent years. Before the cost of energy became a concern, large amounts of glass area were seen as desirable; the 'picture window' was something no house could be without. With the coming of the 'energy crisis' the window very quickly became regarded as a gross energy waster that must be kept to an absolute minimum. Only recently has there been any general recognition that windows can also be energy gainers when the sun is shining on them. This positive, energy-gaining, aspect of windows is dealt with in Subsection 5.6.4 on Enhanced Passive Solar Systems. This subsection will deal only with energy losses through windows and steps the builder can take to minimize them.

4.8.1 Recommendations

- All windows, including glazed doors and sidelights, should be double-glazed.
- Triple glazing should be considered in colder areas (more than, say, 6000 degree days).
- In comparing costs of sealed double or triple glazing, bear in mind that the spacing between the panes has a significant effect on performance.
- Be cautious when considering the use of insulating shutters or blinds.
- Choose windows whose resistance to air leakage is known to be good.
- Install windows in a manner which does not destroy their air-tightness and which creates an insulated, air-tight window/wall joint.

4.8.2 Introduction

Energy is lost through a window in three ways:

- Heat flow through the window.
- Air leakage through the many joints in the window itself.
- Air leakage through the joint between the window and the wall.

There are three actions a builder can take to reduce these losses:

- Choose windows with higher thermal resistance.
- Choose windows with a demonstrated resistance to air leakage.
- Install the windows in a manner which does not reduce their leakage resistance and which minimizes leakage through the window/wall joint.

Each of these actions is discussed in some detail in the following sections.

4.8.3 Increased Thermal Resistance

The most obvious method of increasing the thermal resistance of windows is to add more layers of glazing. Double glazing (either storm sash or sealed double glazing) has come to be regarded as standard practice in Canada. It is prescribed by the Ontario Building Code

and, for most parts of Canada, by CMHC Builders' Bulletin No. 267.

Triple glazing (either sealed triple glazing or sealed double glazing plus storm sash) adds about 20% to the cost of windows. The payback is estimated as shown in Table 4.10.

Quadruple glazing is also available at proportionately higher cost and with even longer payback.

An important factor to keep in mind regarding sealed double or triple glazing is that the space between the panes has a significant effect on the thermal resistance of the unit. The optimum spacing is about 16 mm, with performance falling off rapidly for spacings smaller than that but falling off only moderately for larger spacings.

Metal window frames should incorporate thermal breaks, not only to reduce heat loss but also to avoid serious interior condensation and frosting.

Insulating devices such as thermal shutters and blinds are just beginning to appear on the market. It is too early yet to comment with certainty on their cost-effectiveness, although preliminary studies indicate it may be very good. The advice that can be given at this stage is that builders should select only those devices which appear to provide effective solutions to the fundamental design problems discussed below.

Interior Shutters or Blinds
Because such a device will make the window surface much colder than it would normally be, the shutter or blind must be tightly sealed to prevent humid household air circulating behind it and condensing on the windows. This seal should be much more effective than the seal on the inner pane of double windows, since the shutter will cut off much more heat flow than will an inner pane (Figure 4.27).

Internal insulating devices also create increased potential for thermal breakage of the windows as they warm up after the devices are retracted.

Exterior Shutters
The obvious problem here is to provide an operating mechanism that will remain operable despite long periods of exposure to severe weather conditions. The shutter must also be well sealed against the window in spite of the accumulation of snow and ice. If the shutter cannot close tightly, circulation of cold outside air behind it will greatly reduce its effectiveness.

4.8.4 Resistance to Air Leakage
Little information is available to the builder on the relative air-tightness of various windows. A CMHC acceptance number indicates that a window of the same design has passed an air infiltration test required by a Canadian Standards Association or Canadian Government Specification Board Standard. These numbers are only for metal and plastic windows, however, since it is believed that the acceptability of wood windows can be adequately judged in the field. While there are many wood windows without formal CMHC acceptance which have air leakage resistance as good as, if not better than, CMHC-accepted windows, there is no evidence, other than the manufacturer's claims and reputation, to aid the builder's assessment

Table 4.10 Payback on Triple Glazing

C Degree Days		Type of Heating: Oil	Gas	Elect.
4000	Payback (years)	23	25	20
5000	Payback (years)	19	22	16
6000	Payback (years)	16	19	13

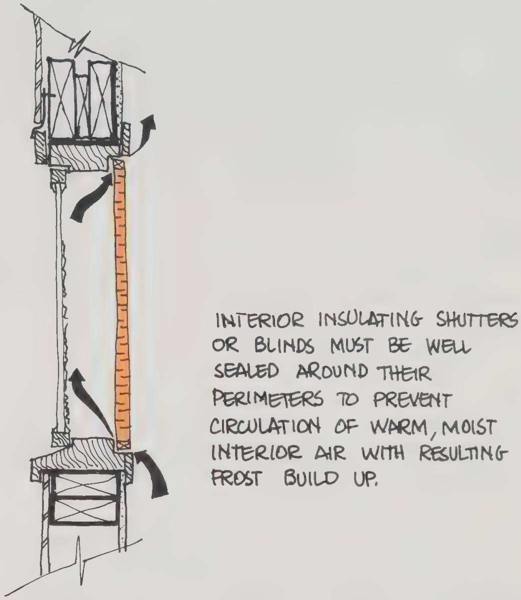


FIGURE 4-27 INTERIOR INSULATING SHUTTER

of their merits. This will be rectified to some extent after May 1980 by which date all windows used in National Housing financed construction must be CMHC-accepted.

A few general guidelines can be given (Figure 4.28). Depending on their operating hardware, casement and awning windows generally have more resistance to air leakage than sliding types including double-hung windows simply because their latching mechanisms provide a greater sealing pressure. Sliding windows (either vertical or horizontal), on the other hand, are limited in sealing pressure so that they can remain easy to open and close. Sliding windows also have a greater length of joint to be weatherstripped. Of the sliding types, the sashless horizontal sliding window has the poorest reputation for air leakage. Certainly its reliance on glass-to-glass contact leaves little tolerance for distortion due to installation. This has been somewhat improved by the introduction of the semi-sashless type which incorporates a light plastic molding-cum-weatherstripping on the edge of the glass.

4.8.5 Installation

Two objectives should be kept in mind when installing windows:

- avoid distortion 'out of square' and 'out of plane'
- create an insulated, air-tight joint between the window and the wall.

One practice that will help in attaining both these objectives is making the rough opening in the framing a generous amount larger than the outside dimensions of the window frame – say an 18 mm margin around the head and jambs. This will make it easier to lift the window into place, leave room for it to be wedged square and provide a space that can readily be filled with insulation (as opposed to trying to jam it into a crack). Figures 4.29, 4.30 and 4.31 show recommended installation practices.

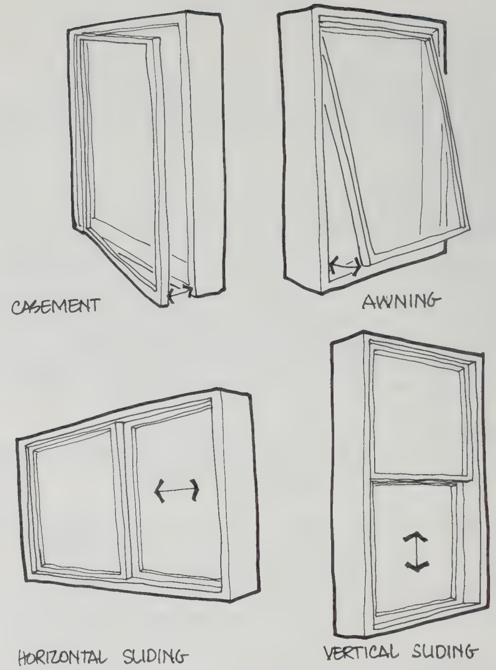
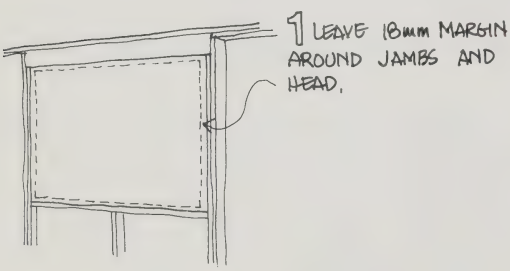
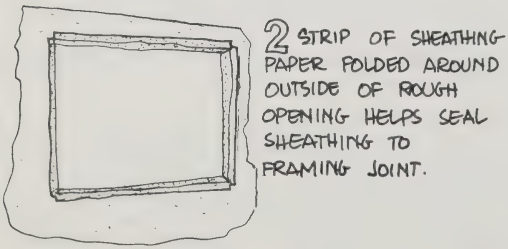
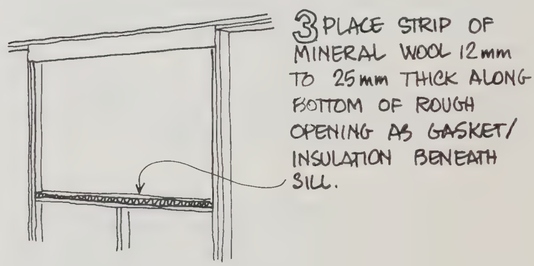


FIGURE 4·28 RELATIVE RESISTANCE TO AIR LEAKAGE.

NOTE: CASEMENT TYPE AND AWNING TYPE WINDOWS HAVE BETTER RESISTANCE TO AIR LEAKAGE THAN SLIDING-TYPE WINDOWS







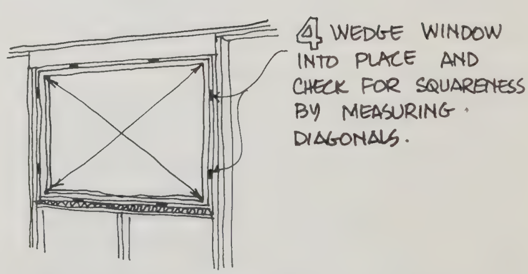


FIGURE 4·29 RECOMMENDED WINDOW INSTALLATION PROCEDURES.

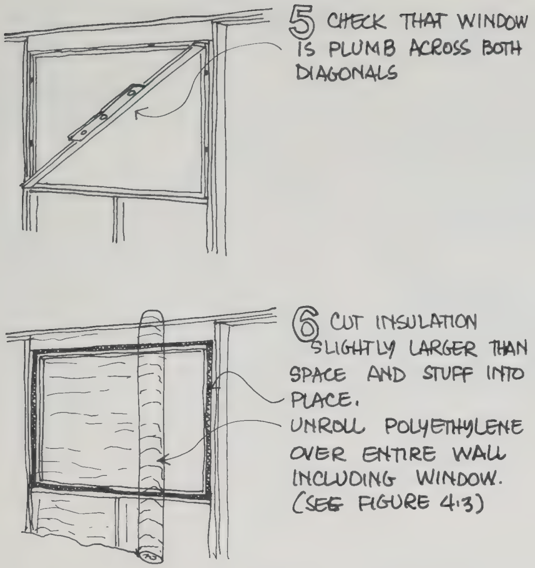


FIGURE 2.29 RECOMMENDED PROCEDURES CONT'D.

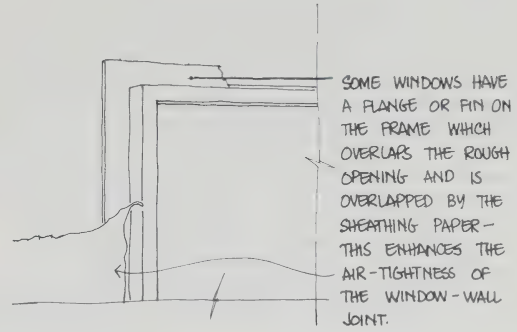


FIGURE 4.30 FLANGE TYPE WINDOWS

4.9 Doors

The energy conservation considerations regarding doors are very similar to those of windows, but higher thermal resistance is achieved somewhat differently. (Sliding glass doors and glass sidelights are essentially the same as large windows. This Subsection deals only with swing-type doors).

4.9.1 Recommendations

- Use insulated doors unless market considerations dictate otherwise.
- Choose weatherstripping that tolerates some movement of the door and can be easily adjusted.
- Advise home purchasers of the need to adjust weatherstripping.
- Install doors in a manner that avoids distortion and creates an insulated, air-tight door/wall joint.

4.9.2 Increased Thermal Resistance

The Ontario Building Code requires that exterior doors 'be provided with storm doors or other means of minimizing heat loss and infiltration'. CMHC Builders' Bulletin No. 267 requires that in most parts of Canada exterior doors have thermal resistance of R 0.7 m^2 °C/W or that storm doors be provided. These two requirements have essentially the same effect, which is to leave builders with three basic choices for exterior doors. In order of increasing thermal resistance they are:

- a solid core wood door plus a storm door (R 0.95)
- an insulated metal or wood door (R 1.0 to more than 2.0)
- an insulated metal or wood door plus a storm door (R 1.6 to more than R 2.6).

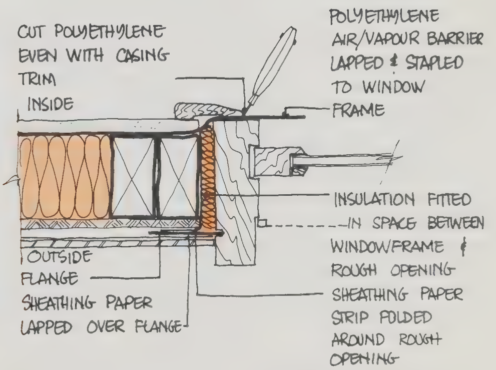


FIGURE 4.31 TYPICAL JAMB SECTION ILLUSTRATING MANY FEATURES OF GOOD WINDOW INSTALLATION PRACTICE.

As the installed cost of solid core wood doors and insulated doors is likely to be about the same and, since the thermal resistance of an insulated door is greater than the combined thermal resistance of a solid core wood door plus a storm door, the economic choice seems obvious. Only such market factors as preference for wood would favour the first option above.

Depending on the quality chosen, a storm door would add from $70 to $150 to the cost of an entrance and would result in an annual energy saving of only about $1.00 compared to a weatherstripped insulated door without a storm door. Thus there is no economic incentive to use storm doors and, again, market factors such as the desire for a screen door in summer will be the ruling considerations.

Some caution is required when combining a storm door with an insulated door, especially if the insulated door incorporates decorative plastic moldings as is common practice. With the glass light of the storm door closed and the door exposed to direct sunlight the temperature between the doors can build up beyond the melting point of the plastic. This combination is not advisable, therefore, on southerly or westerly faces of buildings unless the door is shaded from direct sunlight by trees or overhangs.

4.9.3 Resistance to Air Leakage

Resistance to air leakage around the door is provided by weatherstripping. Unlike windows, doors are not always fitted with weatherstripping by the manufacturer; instead, this is often an on-site installation. Door weatherstripping must also withstand much more demanding conditions than window weatherstripping since

a) doors are opened and closed more often, and
b) are subject to greater changes in shape as the seasons change.

The most important thing to keep in mind in choosing weatherstripping is that doors do, in fact, change shape. Wood doors tend to bow outward in winter due to the difference in the relative humidities of the inside and outside air. Metal doors tend to bow inward due to the difference in temperature between their inside and outside surfaces, although the bowing is normally less than that experienced by wood doors. Weatherstripping should adjust automatically to this movement or be easily adjusted manually. Table 4.11 shows a number of types of weatherstripping and gives their advantages and disadvantages.

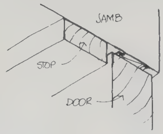
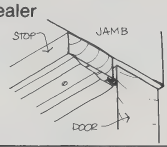
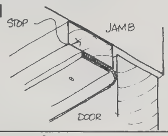
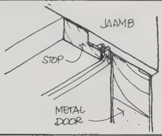
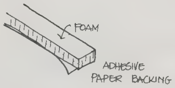
Since doors do change shape, and since it is difficult for weatherstripping to be completely self-adjusting, it follows that the home occupant must take an active role in adjusting the weatherstripping if air leakage between the door and the frame is to be kept to a minimum. It also follows that the builder should make the home occupant aware of this need and provide suitable instructions. This information could be included in a homeowners' manual.

4.9.4 Installation

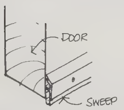
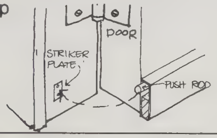
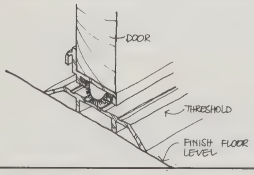
The procedures recommended in Subsection 4.8.5 for the installation of windows apply equally well to the installation of doors. The need to avoid distortion is even more important with doors because even a small angular distortion can result in large gaps over the two metre height of the door.

Table 4.11 Selection of Weatherstripping

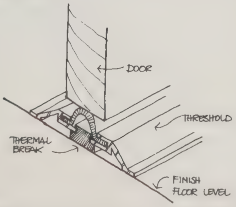
Around doors

Type	Installation, and Materials	Advantages, Disadvantages
Metal tension 	Nails between door and jamb. Spring metal strip works on same principle but is slightly more difficult to install than strip shown at left. Both easier to install if sold with predrilled holes. Bronze, aluminum, stainless steel.	Doesn't show when door is closed. Good control of drafts. Long life. But: difficult to readjust. Easily tampered with.
Rigid metal-backed sealer 	Nails or screws into stop. Screws take longer to install but are easier to adjust than nails. Position to make gentle contact or door will be hard to close. Aluminium, plain or anodized, with vinyl insert.	Can be adjusted if holes are slotted. Good durability. Keep out drafts, water, noise, light, dust, humidity. But: stripping is visible alongside door.
Rolled metal-backed sealer 	Nails into stop. Aluminium with wool, hair or cotton felt, vinyl.	Keeps out drafts, noise, light, dust. But: visible alongside door or window. Not as durable as rigid metal-backed sealer. Not easily adjusted once sealer loses contact with door or window.
Magnetic 	Flexible magnetic seal similar to those used on refrigerators. Usually supplied already installed in frame with pre-hung door.	Very good seal and is flexible enough to accomodate seasonal movement of steel doors. Quite inconspicuous. Only works with steel doors.
Rolled foam 	Adhesive-backed strips of foam simply stick to jamb or stop; vinyl-covered foam strips nail on.	Installs in minutes. Doesn't show. Keeps out drafts, noise, light, dust, and humidity. But: temporary; foam soon flattens, breaks down.

Under doors

Sweep 	Screws into interior side of in-swinging door. Aluminium, stainless steel with sponge, vinyl.	Adjustable. Effective. But: exposed to view. May drag across rugs.
Automatic sweep 	Useful where threshold is flat or there is no threshold. Good durability. But: sweep may not retract quickly enough to pass over edge of threshold or carpet up against door.	Screws onto outside of in-swinging door. Door opens, sweep retracts. Door closes, striker plate causes sweep to lower. Aluminum, plain or anodized, with vinyl, neoprene, or felt drop.
Door shoe 	Fits over door bottom, screws into face. Shoe with slotted screw holes allows adjusting for seal with some margin for error. Aluminum, vinyl insert.	Effective, durable seal. May be used with wood threshold that's not worn down in middle. Usually sold with drip cap that sheds rain. Vinyl insert replaceable. But: before installation, bottom of door may require trimming or door threshold may have to be replaced.

Threshold

Vinyl bulb threshold 	Fits under door; door bottom should have about ⅛-inch bevel to seal against vinyl bubble. Available in different heights. Metal cap with built-in angle available to fit over bottom of door, offers smooth surface. Aluminum, plain or anodized, and vinyl.	Works as combined threshold and weather strip; useful where there's no threshold or wood one is worn out. Provides good weather seal. But: with wear, vinyl bubble will flatten out, tear, lose effectiveness. (Replacement bubbles sold.)

Section 5
Space Heating and Cooling Systems

5.1 Heating Equipment Sizing and Selection

This section discusses selection, sizing, and location of heating equipment.

5.1.1 Recommendations

- Avoid oversizing or guessing at the heating plant capacity.
- Calculate required heating plant capacity in accordance with the methods approved by the Heating, Refrigeration, and Air Conditioning Institute of Canada (HRAI) or American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).
- Ensure that the **output** of the heating equipment being considered is equal to or slightly greater than the calculated heating plant capacity.
- Assess the availability and cost of fuels in the particular location being considered prior to selection of heating equipment.
- Locate heating equipment centrally to loads being served in as far as possible within building constraints.
- Review other sections of the guide to ascertain desired features of the heating equipment.

5.1.2 Heating Equipment Sizing

The heating equipment must be capable of maintaining the house at 22°C during the heating season. In the past, heating equipment installed in houses has been oversized, leading to frequent on-off operation of the equipment, thereby reducing both its efficiency and its service life.

Guessing at heating requirements will generally lead to oversizing. To avoid this problem the size of the heating equipment should be determined from the reliable heat loss formulas published by HRAI or ASHRAE.

Based on these calculations, units should be selected which have a heat output equal to or slightly greater than the calculated heating load. Installing the smallest capacity of equipment to meet the loads will save both energy and money.

5.1.3 Heating Equipment Selection and Location

The choice of fuel will be largely based on the availability and relative cost of oil, gas, and electricity. When comparing these fuels it is important to obtain the cost per unit of energy delivered to the house, i.e. $/GJ (Gigajoules). Appendix E provides conversion factors to assist in this calculation.

In order to determine the cost of energy delivered to the house, the average annual or seasonal efficiency of the heating equipment must be used. Typical heating equipment in use today has the following seasonal efficiencies: gas 60%; oil 65%; electric resistance heating 100%. Dividing the purchase price of the fuels by the appropriate seasonal efficiency will provide the delivered cost of heat to the house per unit of energy, $/GJ. See Table 5.1 for example.

TABLE 5.1

Delivered Cost of Heat

	Purchase Price of Fuel $/GJ	Heating Equipment Seasonal Efficiency	Delivered Cost of Heat to house $/GJ
Gas	$2.90	0.65	$4.46
Oil	$3.50	0.65	$5.38
Electricity	$7.30	1.00	$7.30

The heating plant should be located as close as possible to the centre of the loads being served in order to reduce the size of the distribution system. Building constraints such as planned uses for the spaces should be considered to ensure that the heating equipment will not interfere with the intended use of space.

Prior to selection of heating equipment, Subsections 5.2 to 5.7 of this Guide should be reviewed.

5.2 Combustion Furnaces

This section examines the options available for improving the efficiency of combustion furnaces. The alternatives for oil and gas furnaces are discussed in terms of capital and operating costs.

5.2.1 Recommendations

Gas Furnaces

- Provide furnaces equipped with factory-fitted spark ignition devices.
- Use furnaces with factory installed flue dampers where permitted.

Oil Furnaces

- Choose units with a factory installed flue damper.
- Specify units equipped with oil line solenoid valve and flame retention head as a single package.

5.2.2 Gas Furnaces

Gas furnaces are available that eliminate the need for a pilot light through the use of an intermittent ignition device, or electronic spark ignition (Figure 5.1). When the house thermostat calls for heat, the pilot jet is turned on and ignited by an electric spark. Table 5.2 shows the additional cost and savings available from such devices.

An automatic flue damper is available that reduces air loss during periods when the furnace is not operating. When the house thermostat turns the furnace off, the flue damper closes, trapping the residual heat in the combustion chamber and heat exchanger, from which it is circulated to the house by the blower. When heating is required, the vent damper reopens before the burners are ignited, allowing for the escape of combustion fumes. A safety feature prevents the burners from operating if the damper fails to open.

5.2.3 Oil Furnaces

Oil-fired furnaces begin their cycle of operation with a simultaneous activation of the oil pump, combustion air fan and spark ignition. A spray of oil droplets is ignited by the electrodes and the products of combustion give up much of their heat before leaving the furnace and venting to the atmosphere.

During the first few moments of operation – anywhere from 10 to 30 seconds – combustion is usually incomplete because of low pressure in the fuel line and inadequate draft from the burner fan. This is the main

Table 5.2
Options for Increased Energy Efficiency in Gas Furnaces

Option	Availability	Annual Energy Savings* GJ ($)	Capital Cost $	Payback Period Yrs
Spark Ignition	Factory Installed	6-7 ($ 18-22)	100	6-5
Flue Damper	Factory Installed	5-10 ($ 15-30)	85	6-3

*Energy savings from a flue damper will depend on furnace size, building type and location. (Low figure indicates energy savings for a split level house in a 4000 DD (°C) zone high figure indicates energy savings for a split level house in 6000 DD (°C) zone).

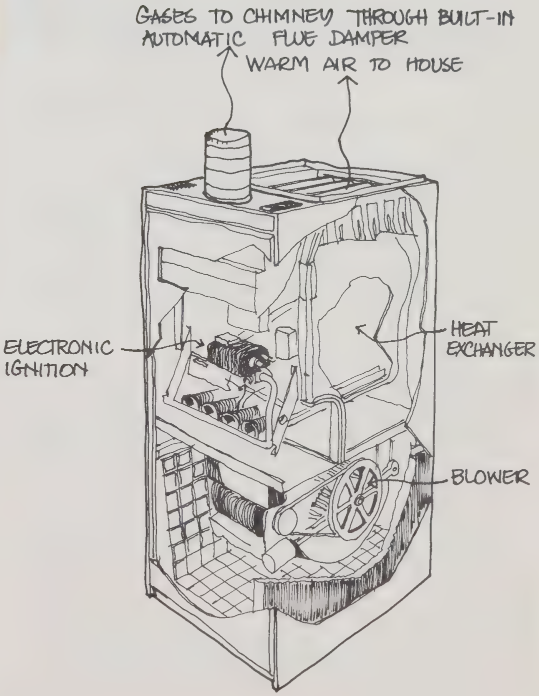


FIGURE 5·1
GAS FURNACE WITH SPARK IGNITION AND FLUE DAMPER

cause of soot buildup in oil furnaces, but incomplete combustion also occurs, to a lesser degree, at the end of the firing cycle due to the failure of the fuel pump to shut off sharply, causing 'burner run-on'.

Both these problems can be overcome by the use of a delayed-action solenoid valve between the fuel pump and the nozzle (Figure 5.2). When the furnace starts up, the solenoid valve remains closed to keep the fuel oil from the nozzle until the pump has reached the required pressure and the burner fan has had time to start the air flow through the combustion chamber. At the end of the firing cycle the solenoid valve cuts the fuel off sharply, preventing 'burner run-on'. Savings come through reduced oil wastage during start-up and shut-down, and through improved operating efficiency. Further savings are possible from the reduced cleaning frequency.

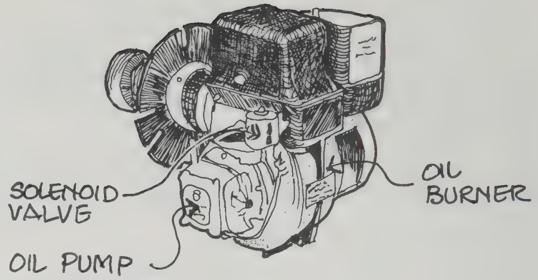


FIGURE 5·2
OIL BURNER WITH SOLENOID VALVE

Flame retention heads fit on the end of the oil burner to produce a flame pattern that operates at higher carbon dioxide levels and, therefore, at higher efficiencies (Figure 5.3). Most new oil burners are equipped with flame retention heads as standard equipment, but a builder should make sure that these are what he gets, in fact, from his heating contractor.

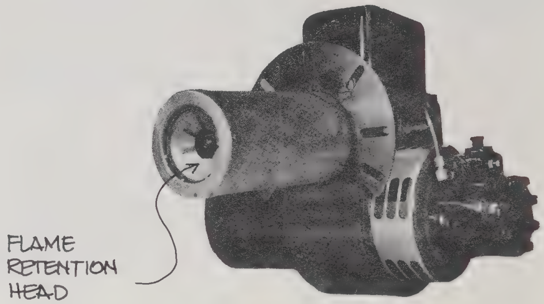


FIGURE 5·3
OIL BURNER WITH FLAME RETENTION HEAD

Flue dampers for oil furnaces act in much the same way as those on gas furnaces.[1] They trap the residual heat inside the furnace, and reduce the loss of inside air up the chimney.

Each of the above options is summarized in Table 5.3.

Table 5.3
Options for Increased Energy Efficiency in Oil Furnaces

Option	Avail-ability	Annual Energy Savings* GJ ($)	Cost $	Payback Yrs
Solenoid Valve	Factory Installed	1-2 ($ 3-7)	9	3-2
Flame Retention Head	Factory Installed	6-13 ($ 21-45)	N/A	immediate
Flue Damper	Factory Installed	4-8 ($ 14-28)	85	6-3

*Energy savings will depend on furnace size, building type and location. Savings are not necessarily additive if more than one option is chosen. (Low figure indicates energy savings for a split level house in a 4000 DD (°C) zone, high figure indicates energy savings for a split level house in a 6000 DD (°C) zone).

5.3 Electric Resistance Systems

This section examines two alternative systems for electric resistance heating. Recommendations focus on proper installation practices to achieve maximum energy conservation. The conversion of electricity into heat is assumed to be 100 percent efficient for both the electric baseboard and the electric furnace case.

5.3.1 Recommendations

Electric Baseboard

- Where electric baseboard heaters are used, supply each room with a wall-mounted low voltage thermostat, or a CSA performance certified line voltage, wall-mounted thermostat.

- Built-in thermostats may be used in baseboard heaters serving the kitchen, bathroom, service or storage rooms, and vestibules.

Electric Furnaces

- Where forced air electric furnaces are used, provide a low voltage thermostat and heater control that permits staging of the heating elements.

5.3.2 Electric Baseboard

Baseboard heaters use resistance wires or rods to produce heat and are usually located in each room of the house, with individual room temperature control. This system has a flexibility that central systems do not, in that rooms can be kept at different temperatures or can be closed off and left at lower temperatures.

1 The use of flue dampers on oil furnaces is permitted as long as they are CSA and/or ULC approved.

5.3.3 Electric Furnaces

Forced air electric furnaces are centrally located and operate like a conventional combustion furnace, using a similar blower and ductwork for distributing the heat throughout the house. The thermostat turns on the heating coils in stages when there is a demand for heat. The output capacity is determined by the number of heating coils, or the kilowatt rating of the furnace (Figure 5.4). Forced air electric furnaces have more flexibility than baseboard heaters, allowing for the addition of such features as air filters, air conditioners, and heat pumps. They also provide air circulation which reduces the buildup of humidity and odours in local areas.

5.4 Heat Pumps and Central Air Conditioning

This section examines heat pumps and central air conditioning systems in terms of their capital and operating cost.

5.4.1 Recommendations

Heat Pumps

- If a heat pump is to be used in locations with 5000 DD (°C) or less, it should have a coefficient of performance (COP) greater than 1 at –12°C.

- If a heat pump is to be used in locations with more than 5000 DD (°C) provide a machine with a COP greater than 1 at –23°C.

- If an add-on heat pump system is to be used, it should consist of an efficient furnace as outlined in Subsections 5.2.2 and 5.2.3 and a heat pump with performances as outlined above.

- Employ the services of a contractor skilled in the installation of heat pumps.

- Ensure the availability of a qualified heat pump service contractor in the area.

- Refer to Subsection 5.1.3 for indoor unit location, and to Subsection 5.5.2 for distribution system considerations.

Central Air Conditioning

- Refer to Subsection 5.7 for an alternative to central air conditioning systems.

If a central air conditioning system is required:

- Provide a central air conditioning system with a minimum energy efficiency ratio (EER) of 10 kJ per watt.

- Retain the services of a contractor skilled in the installation of central air conditioning systems.

- Ensure that the air conditioning system installed is the minimum required to achieve desired space conditions. Size equipment in accordance with HRAI or ASHRAE standards.

- Consider the use of a heat pump system in lieu of an air-conditioning system only.

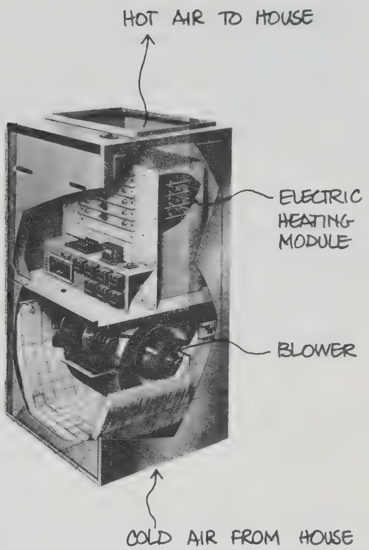


FIGURE 5·4
CENTRAL FORCED AIR ELECTRIC FURNACE

5.4.2 Air to Air Heat Pumps

An air to air heat pump is another form of electric heating. It uses electrical energy to withdraw heat from the outside air, raises its temperature and discharges its heat to the space being heated. Mechanically it is simply a refrigerator working in reverse (Figure 5.5). In the summertime the cycle may be reversed to cool the building and transfer the heat to outdoors, operating as an air conditioner.

The efficiency of this heat transfer is referred to as the coefficient of performance (COP) of the machine. Simply stated the COP is the net useful heating effect divided by the energy supplied to the equipment. As the heat pump may be used as an air conditioner during the summer this section accounts for the energy used both to provide summertime cooling and wintertime heating.

Air to air heat pumps are available in three basic designs, single-speed compressor, two-speed compressor, and an add-on heat pump system.

Single-speed Heat Pump

A single-speed heat pump operates on demand from the house thermostat to supply the necessary heat. If the compressor is unable to meet the load, electrical resistance heating elements switch on to provide the additional heat required. Table 5.4 examines the economics of a single-speed heat pump.

Two-speed Heat Pump

Research work is currently underway by Ontario Hydro, National Research Council and others to develop a heat pump more suited to the Canadian climate. One recent improvement is a heat pump with a two-speed compressor. Such a machine offers higher COP's at below-freezing outdoor air temperatures than the single-speed machine.

Operation of a two-speed heat pump is identical to the single-speed machine, except that the compressor runs faster at sub-freezing temperatures. The improved efficiency can be seen in Table 5.4.

Add-on Heat Pump

The add-on heat pump is identical to the single- and two-speed heat pumps except that the auxiliary energy required to meet the heating load is supplied by a combustion furnace, and the heat pump unit does not function below approximately 0°C (Figure 5.6). The major benefit of this system arises from the fact that combustion heating is currently less expensive than electrical resistance heating (see Subsection 5.1.2). Operation of a single-speed add-on heat pump system for conditions identical to single- and two-speed compressor heat pumps previously examined is presented in Table 5.4.

Heat pump economics are significantly affected by the high initial capital cost. If the cost of an air conditioning system is subtracted from the cost of a heat pump system (common marketing practice), then heat pumps would appear to cost $1,200 less than indicated in Table 5.4.

The COP of a single-speed heat pump is usually greater than 1 at –12°C. These machines are more cost effective in areas with 5000 DD °C or less. Two-speed heat pumps have a COP greater than 1 at –23°C These

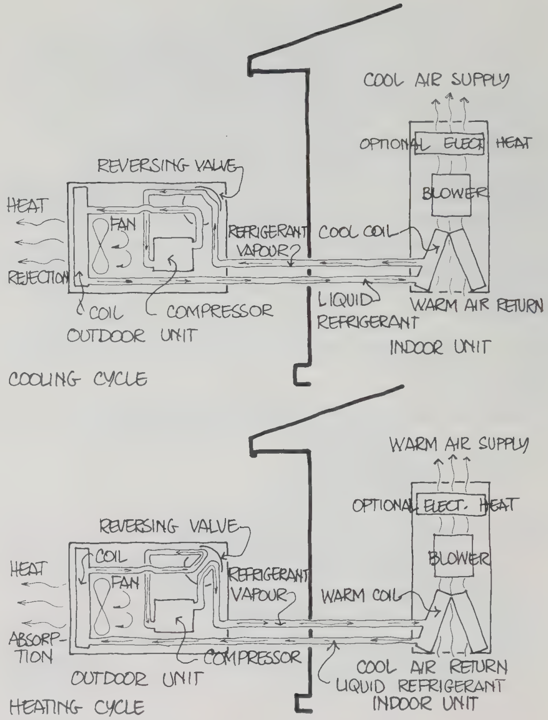


FIGURE 5·5
BASIC HEAT PUMP OPERATION

Table 5.4
Economic Comparison of Heat Pump Systems

System	First Year Purchased* Energy Cost $	Capital Cost $	Pay-back** Yrs
Electrical Resistance System	$380-$570	Base Case	–
Gas Furnace	$255-$380	Base Case	–
Single-Speed Standard Heat Pump System	$290-$475	$2400	21-20
Two-Speed Standard Heat Pump System	$270-$395	$3000	22-14
Add-on Heat Pump System	$255-$380	$2200	14-11

*Low figures are for 4000 DD (°C) zone and high figures are for 6000 DD (°C) zone.
**Payback comparison between electrical resistance system and heat pump systems only.

machines provide a more cost effective alternative in locations with more than 5000 DD °C.

Add-on heat pumps should consist of the appropriate selection of a heat pump machine described above, and an efficient furnace as described in Subsection 5.2. In this manner an efficient heating package will be ensured.

Even the best heat pump system is not much good if it is not properly installed. Ontario Hydro found that a significant percentage of heat pumps were not properly installed in the first place, and further, that the servicing of these machines had actually reduced the performance because of improper modifications of the control setpoints. It is important that only contractors who are skilled in the installation of heat pumps be used. Installation must be in accordance with CSA Standard C273.5 M. The availability of qualified servicemen must also be assured.

Location of the indoor unit, thermostat location, and ductwork considerations are covered in Subsections 5.2.2, 5.5.4 and 5.5.2 respectively.

5.4.3 Central Air Conditioning System

An air conditioning system cools the air that is circulated through the house by the furnace blower, by means of a coil located in the discharge duct work from the furnace. The heat that is removed from the house is transferred outdoors by a condensing unit located outside the house (Figure 5.7). An alternative to using mechanical refrigeration to cool the house is presented in Subsection 5.7.

Central air conditioning systems require electrical energy to operate the compressor, but some are more efficient than others. Manufacturers rate their products in terms of an energy efficiency ratio, EER. This is simply the amount of heat removed from the space (in kJ) divided by the power required in watts. An efficient machine will have an EER of 10 or greater.

Like heat pumps, air conditioning equipment should be installed by qualified contractors to ensure proper operation. Installation of the smallest unit that will do the job will save both money and energy. Equipment should be sized in accordance with HRAI or ASHRAE standards. Oversized equipment will do a poor job of reducing humidity and may have a shorter life due to increased cycling.

If air conditioning is to be provided, consider installation of a heat pump instead. The extra capital cost associated with the heat pump, over an air conditioning only system, is justified by its energy savings.

5.5 Heat Delivery and Control Systems

This section examines the requirements of heat distribution and control systems that will reduce problems of uneven heating throughout the house.

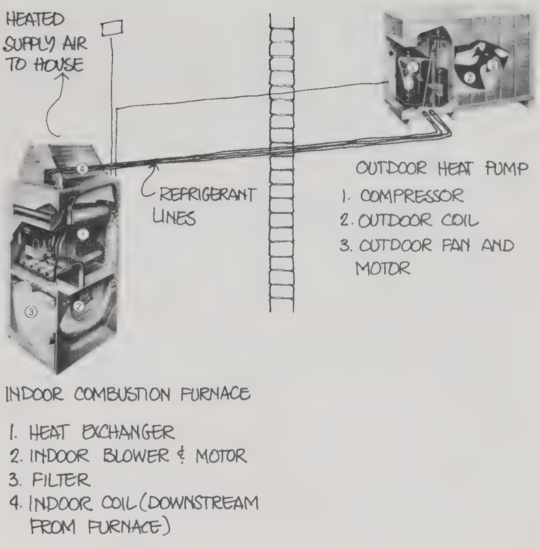


FIGURE 5.6
ADD-ON HEAT PUMP SYSTEM

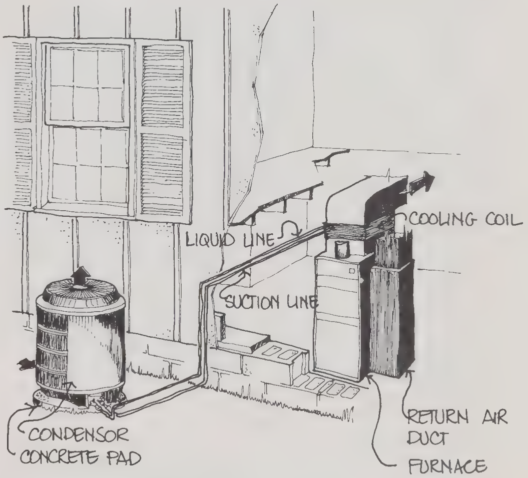


FIGURE 5.7
TYPICAL AIR CONDITIONING SYSTEM

5.5.1 Recommendations

Forced Air Systems

- Install ductwork, diffusers and grilles in accordance with standards established by HRAI and ASHRAE. In particular:
- Provide balancing dampers in ductwork at all takeoffs
- Provide adjustable diffusers
- Channel return air from house to heating equipment using a minimum of one collection point per floor
- Where enclosed joist spaces are used for return air, they must be tightly sealed and of adequate free area
- All joints in ductwork should be taped
- Wherever possible, lay out ductwork so that straight unobstructed runs are obtained
- Insulation of ductwork to R-0.5 will assist even distribution of heat within the house
- Warm air grilles in rooms located above unheated spaces should direct air across the floors rather than up the walls.
- Air systems should be balanced in accordance with practices established by HRAI or ASHRAE. The occupant of the house should be instructed how to change the warm air distribution within the house to suit personal desires.
- Ducts should be arranged so that they do not pass through unheated spaces or exterior walls.
- Provide a blower with sufficient capacity to supply 0.2 m^3 of air per minute per square metre of floor area being heated.
- If central air conditioning is to be added to the distribution system, the blower must be capable of providing the additional static pressure required.

Hot Water Systems

- Provide a self-balancing water heating system either using two pipes with balancing valves, or a single pipe system with automatic control valves.
- Provide balancing and shut-off valves on all radiation units.
- Install foil-faced insulation board between radiators and external walls to reduce heat losses to exterior of building.
- Insulate all supply water piping to R-1.

Heating System Controls

- Supply low voltage automatic setback thermostats.
- Locate thermostat(s) as follows:
  1. Mount on an inside partition about 1.5 metres from the floor.

2. Never locate on an outside wall, and keep away from windows and doors that open to the outside.

3. Avoid mounting on either side of a wall exposed to direct sunshine; near wall areas warmed by the kitchen range or refrigerator on the other side; or on walls containing pipes or air ducts.

4. Locate away from radiators, warm air registers, and any heat-releasing appliances (T.V., lamps, etc.).

5. Select an exposed area where air circulation is good, but not drafty.

- Refer to Subsection 5.3 for electrical resistance heating system thermostat recommendations.

5.5.2 Forced Air Systems
Forced air systems distribute air, warmed by the heating equipment, to the residence by a supply and return duct system. To prevent overheating certain areas of the house while others remain too cold for occupant comfort, which causes the occupant to raise the thermostat setting, a proper distribution system is required. Construction of such a distribution system may be accomplished through adherence to sizing and installation practices established by HRAI and ASHRAE. The most important and often overlooked requirements are listed in Subsection 5.5.1 Recommendations.

Even the best duct system is of little benefit if the air supply is not properly balanced in accordance with standards established by HRAI or ASHRAE. Also, the occupant of the house should be told how to modify the temperature of various rooms to suit personal requirements through adjustment of the air flows.

To reduce unwanted heat losses, ducts should be arranged so that they do not pass through unheated spaces or exterior walls. If this is not possible due to building constraints, the ducts should be taped at the joints and insulated to the R value of the space or R-1, whichever is greater (Figure 5.8).

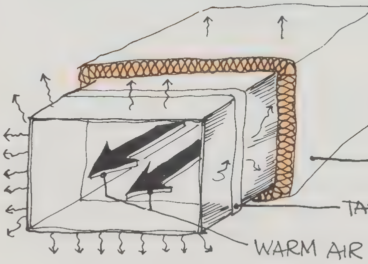


FIGURE 5·8 INSULATION OF HEATING DUCTS

A more even temperature throughout the house can be achieved by increasing the speed of the blower fan beyond the minimum required by the heating equipment, because this will reduce the temperature difference between the supply and return air. A flow rate of 0.2 m^3 of air per minute per square meter of floor area is desirable. In addition to improved occupant comfort, a higher air flow rate also makes it easier to add such items as a heat pump or air conditioner in the future, because these require additional fan pressure to allow for the pressure drop through the coil.

5.5.3 Hot Water Systems
Hot water heating systems are generally used in multi-unit residential buildings, where one heating plant supplies the heat for the entire building. Even so, they are sometimes used for single-family homes.

The water is heated to 50°-100°C in the boiler and pumped through the system to radiators located in individual rooms before returning to the boiler for reheating. Most boilers have a 5-10 litre capacity that

allows quick response to a heating demand and keeps standby losses to a minimum. Boilers may be fired by gas, oil or electricity.

To provide an even distribution of heat to the various rooms in the house, a self-balancing system such as shown in Figure 5.9 or 5.10 should be used. The two-pipe system will supply hot water of uniform temperature to each radiator. Balancing valves on the radiators permit individual adjustment of heat supply. The one-pipe system with automatic control valves will vary the flow of water through the radiators to meet the room load.

Regardless of the system used, balancing and shut-off valves should be provided on each radiator to permit the system to be balanced, and to allow the heat to be shut off in unoccupied rooms.

Radiators supply heat to the room through a combination of convection and radiation. A foil-faced insulating board placed between the radiator and external wall will reduce heat losses to the exterior of the building.

Like the ducts in a forced air distribution system, the plumbing in a hot water heating system should be arranged so that the pipes will not pass through unheated spaces or through exterior walls. All water supply piping should be insulated to R-1 to reduce unwanted heat losses and assure a more even distribution.

5.5.4 Heating System Controls

In general, low voltage room thermostats are best for temperature control. They are connected to a relay switch that controls the on-off operation of the heating plant. Low voltage thermostats are sensitive to small changes in room temperature and will turn the furnace on when the temperature falls as little as 0.5°C below the thermostat setting, and off when the temperature rises only 0.5°C above the setting. This type is preferable to the less sensitive line voltage thermostat, which permits the temperature to drop several degrees below the setting before switching the heating plant on. This can result in higher fuel consumption if the homeowner turns the thermostat up to avoid the uncomfortable drop in temperature. For electrical resistance heating thermostats, see Subsection 5.3.

Significant energy savings are possible through reduction of the thermostat setting for the periods when the home is unoccupied, or at night when a lower temperature would go unnoticed. This technique, known as thermostat setback can be performed manually or automatically, depending on the type of thermostat used. Energy savings depend on the time and amount of the setback.

These will vary widely with different occupants, but typical night-time setback energy savings for various thermostat settings are illustrated in Table 5.5.

In order for the thermostat to function properly it must be mounted where it will not be influenced by artificial heat gains or losses. Recommendations on locations of the thermostat are contained in Subsection 5.5.1.

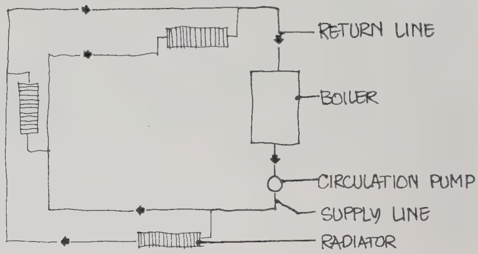


FIGURE 5.9 TWO-PIPE HOT WATER SYSTEM

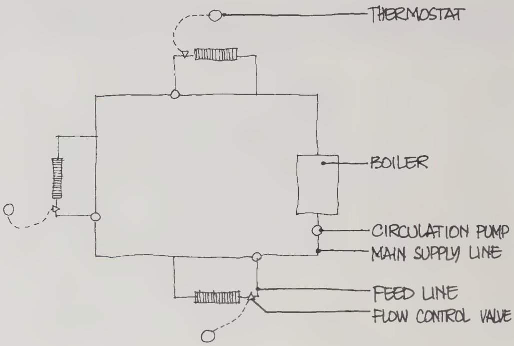


FIGURE 5.10 ONE-PIPE HOT WATER SYSTEM WITH INDIVIDUAL RADIATOR CONTROL

Table 5.5
Annual Energy Savings from Night Time Thermostat Setback Assuming Daytime Setting of 22°C

Temperature Setting	Annual Energy Savings* GJ ($)	Cost** $	Payback Yrs
22°C	Base Case		
20°C	4-8 ($ 12-24)	90	8-4
18°C	6-12 ($ 18-36)	90	7-3
16°C	8-16 ($ 24-48)	90	5-2

*Energy savings will depend on furnace size, building type and location. (Low figures indicate energy savings for a split level house in a 4000 DD (°C) zone, high figures indicate energy savings for a split level house in a 6000 DD (°C) zone, using gas. With a setback period of 8 hours.)
**Accounting for automatic setback thermostat.

5.6 Supplemental Heating Systems

This section examines heating systems which are not generally used as the sole source of heat in a residence, including fireplaces, wood stoves, enhanced passive solar systems, active solar space heating systems, and active solar swimming pool systems.

5.6.1 Recommendations

Fireplaces

- Where fireplaces are provided, incorporate glass doors on the front of the fireplace and a dampered combustion air supply directly from outside to the fire box.
- Provide heat-circulating fireplaces with natural or forced convection of room air around the fire box.
- Consider using free-standing combination fireplace-stoves instead of built-in fireplaces.

Woodstoves

- Ensure that the woodstoves are installed in accordance with manufacturers recommendations and existing codes, such as the Canadian Heating Ventilation and Air Conditioning Code (CHVAC) to prevent fire hazards. See also CMHC 'Heating with Wood Safely,' NHA5178, Feb. '79.
- Wood stoves must not be combined with standard combustion furnaces unless they are purchased from a manufacturer as a single unit, and are approved for the intended use by the regulating authorities.
- Provide efficient airtight wood stoves.
- Install louvres communicating with other parts of the house to promote convection of room air over the stove.

Enhanced Passive Solar Systems

- Refer to Subsections 2.4 and 2.5 for recommendations on siting, landscaping and window considerations.
- Review Subsection 5.6.4 with regard to enhanced passive solar systems.

Active Solar Space Heating Systems

- If a building is to be constructed with a solar heating system, engage the services of an experienced design team and contractor.
- Carefully assess all ramifications of a solar system on other building components prior to construction, such as the strength of the roof framing, snow and wind loading, etc.
- Build solar systems for houses only when the design of such a house has incorporated a solar heating system from the outset to ensure compatibility and integrity of solar components with building structure.

- Provide an auxiliary heating system capable of meeting the heating load requirements of a building, regardless of the type of solar system being provided to ensure reliable supply of heat to the building.

Active Solar Swimming Pool Systems

- Provide removable insulation blanket for the swimming pool. The blanket should be installed regardless of the heating system being used.

- Instead of the conventional fossil fuel-fired swimming pool heater, provide a prefabricated, solar heating system capable of meeting the heat demand of the swimming pool from May 15 to Sept. 15.

- A solar heating system should be provided and installed by the manufacturer's representative.

5.6.2 Fireplaces

Traditional built-in fireplaces can lead to increased fuel consumption in houses due to their inefficient design.

A free-standing prefabricated metal fireplace (Figure 5.11) will deliver more heat directly to the interior space than a traditional built-in masonry fireplace (Figure 5.12) located along the exterior wall, because more of the hot fireplace structure is exposed to the room air. The main advantage of the built-in, however, is that by virtue of its design it lends itself to easy adaption of various alternatives for improved efficiency.

All of the air that fireplaces exhaust through the chimney must be replaced by cold outdoor air. The heat required to raise the temperature of this outdoor air may exceed the heat supplied by the fireplace. Infiltration can be reduced if outside air is vented directly to the fireplace (Figure 5.13). The flow of air into the fireplace is best controlled by two dampers – one vent damper and one flue damper – otherwise the fire will burn too quickly and take much of the heat up the chimney. Glass doors must also be added to the front of the fireplace to reduce the amount of room air that is used for combustion. Use of outdoor vents and glass doors can raise the seasonal efficiency of a fireplace to 25%, which is well above the seasonal losses created by traditional fireplaces.

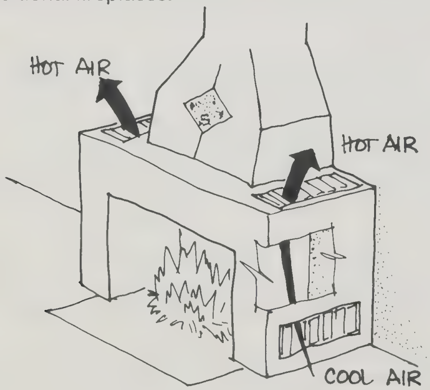


FIGURE 5·14 CIRCULATING FIREPLACE

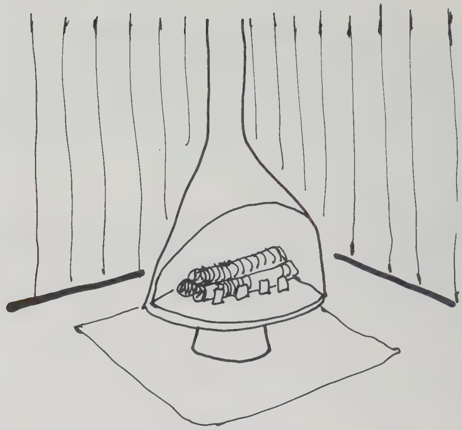


FIGURE 5·11 TYPICAL FREE-STANDING PREFABRICATED METAL FIREPLACE.

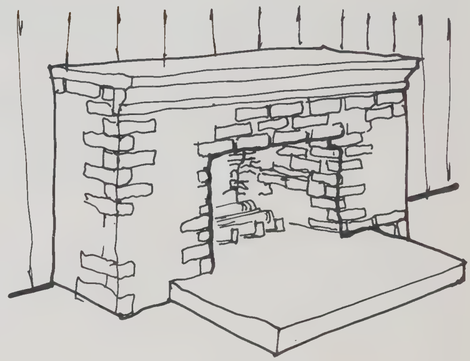


FIGURE 5·12 TYPICAL BUILT-IN MASONRY FIREPLACE.

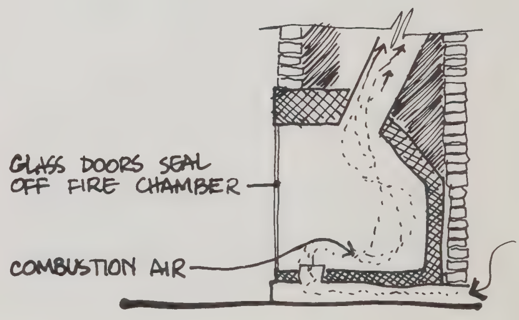


FIGURE 5·13 ENERGY CONSERVING FIREPLACE

A built-in circulating fireplace allows for greater heat recovery by drawing in cool room air through vents located near the bottom and circulating it through the double-walled sheet metal firebox where the air picks up heat and returns to the living area via the upper vents (Figure 5.14). Circulation occurs by natural convection, although some units use blowers to increase the air circulation rate.

An interesting alternative to the built-in fireplace is the combination stove-fireplace. In this, the front door of the stove opens to permit direct viewing of the fire. When the door is closed, the unit has the seasonal efficiency of a good wood stove but can still provide the attractive features of a fireplace when the doors are opened.

Fireplaces should not be used in tight houses without installing outside vents for combustion air. Lack of adequate venting could lead to starvation of the furnace, with possibly serious results. Refer to combustion equipment codes to ensure sufficient air for proper furnace operation.

5.6.3 Woodstoves

In areas where wood is available at little or no cost to the occupant of a house, woodstoves are becoming popular for offsetting the space heating load. It is important that any wood-burning equipment be installed in accordance with manufacturers recommendations and existing codes such as CHVAC to prevent fire hazards. A sample requirement is illustrated in Figure 5.15.

Until appropriate standards and equipment are developed, no wood-burning equipment should be connected to existing oil, gas, or electric furnaces. The potential hazards arising from interconnection include the danger of ignition if a gas leak develops, and overheating of the ducts if electrical power to the blower fan is interrupted. More importantly, such interconnection would void CSA or ULC certification on existing furnaces. Several combination furnaces designed to use both wood and fossil fuel have been approved, however.

When considering such units, make sure that they carry CSA and ULC certification. Remember too, that installation requirements of ductwork and flues attached to woodburning equipment are different from standard furnaces. Careful attention to the appropriate codes is necessary to ensure occupant safety.

Modern airtight wood stoves have seasonal efficiencies up to 65 percent. Since they are airtight, the air supply to the stove can be controlled, thus reducing drafts and extending the wood's burning time. Slow burning increases the rate of creosote build-up in the flue, however. Therefore ready access is required to the chimney to permit cleaning.

To obtain maximum benefit from a wood stove, registers should be located at the ceiling and floor levels of the room in which the stove is located to promote the circulation of warm air to adjacent rooms. Fans can be used to increase the air flow (Figure 5.16).

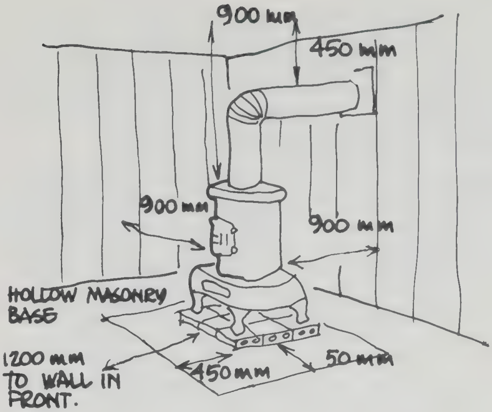


FIGURE 5·15 WOOD STOVE CLEARANCES

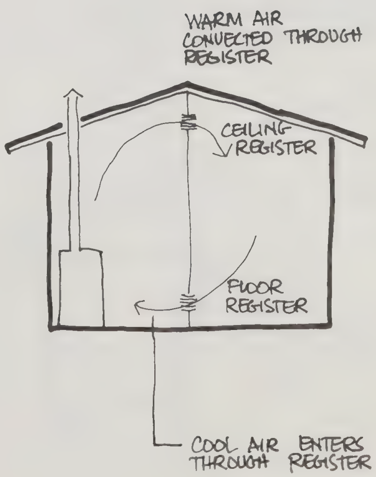


FIGURE 5·16 REGISTERS TO PROMOTE AIR CIRCULATION

5.6.4 Enhanced Passive Solar Systems

Use of solar radiation to offset the heating load of a building through positioning of the house and windows was examined in Subsections 2.4 and 2.5. This subsection presents methods that will increase the heat delivered to a house by solar radiation.

Passive solar design relies on southern orientation of the building, with few windows on the east and west sides, and minimal window area to the north. In-coming sunlight will generate heat when it strikes any object. Where the ratio of window area to floor area is large, overheating may occur. In order to prevent this, sufficient 'thermal mass' (heat storage capacity) such as concrete floor slabs, heavy concrete walls (Figure 5.17), water filled drums (Figure 5.18), etc. must be provided to absorb the heat from the sunlight and release the stored heat back into the interior space when sunlight becomes unavailable.

Two basic designs that will enhance 'solar gains' are:

1. Direct gain systems – where the living space is directly heated by the sun, and the solar heat is stored in the mass of the house itself. See Subsections 2.4 and 2.5 (Figure 5.19).

2. Mass wall system – where a glass-covered mass collects and stores heat directly from the sun, and then transfers heat to the living space later (Figure 5.20).

Variations on the mass wall system are the Trombe wall (Figure 5.21) and attached greenhouses (Figure 5.22).

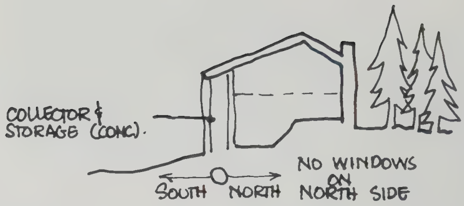


FIGURE 5·17 MASSWALL COLLECTOR/STORAGE

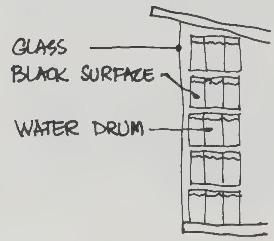


FIGURE 5·18 "DRUM WALL" COLLECTOR/STORAGE

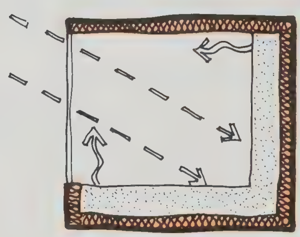


FIGURE 5·19 DIRECT GAIN SYSTEM

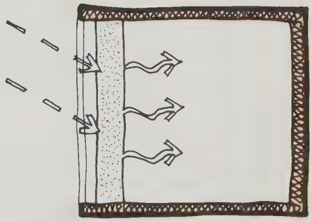


FIGURE 5·20 MASS WALL SYSTEM

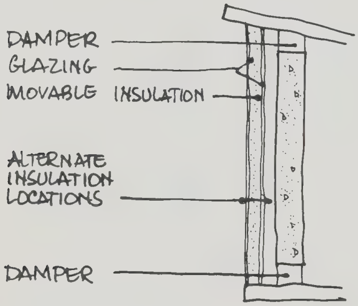


FIGURE 5·21 TROMBE WALL

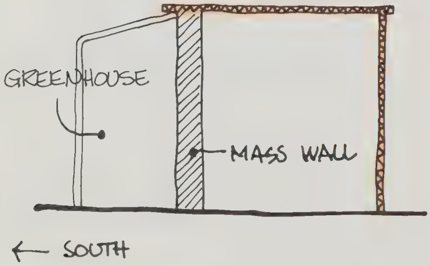


FIGURE 5·22 ATTACHED GREENHOUSE & MASS WALL

The Trombe wall not only radiates heat to the interior, but heats and circulates household air by convection, drawing it in at the bottom and discharging it at the top (Figure 5.23). In summer, this air movement can provide natural ventilation if a vent is provided to the outdoors (Figure 5.24). The attached greenhouse will also circulate hot air to the interior space, as required, but can create humidity problems within the house.

5.6.5 Active Solar Space Heating Systems

There are two basic types of solar space heating systems, a short term storage solar system, and an annual storage solar system. At the present time in Canada, neither of these systems is currently cost effective for individual residential applications. Their payback periods range from 20 years to 50 years, or longer at current energy rates.

For each of these systems there is a choice between using air or water to circulate the heat. Air is often used on short term storage systems because of the relatively low cost of the gravel storage beds that are used. Water – or occasionally some other liquid – is used for annual storage systems to reduce the storage volume. Liquids are also used in short term heating systems. Water systems must, however, be protected from freezing in a failsafe manner.

In the short term storage system, a heat transfer medium circulates through the solar collectors, where it is warmed, to a thermal storage vessel (Figure 5.25), where it gives up its heat. Heat is withdrawn from the storage vessel for space heating as required. Due to the small storage vessel used, short term storage systems are designed to supply about 50% of the annual space heating needs. A typical short term solar heating system for a house requires 65 m^2 of solar collectors and 4.5 m^3 of storage.

Annual storage systems operate in an identical manner, but the storage vessel is considerably larger (Figure 5.24). Annual storage systems can be designed to supply 100% of the annual space heating requirements of a building. A typical home installation will require 46 m^2 of solar collectors and 150 m^3 of storage.

Solar heating systems require a large, unobstructed, south-facing roof area for the solar collectors, sloped at an angle above the horizontal approximately equal to the latitude plus 15°. Refer to Subsection 2.2.4 in regards to siting considerations. Provision must also be made for the storage vessel. Experienced designers and contractors should be retained to undertake the design and construction of any solar heating system.

Roof-mounted solar collectors will increase the load that must be carried by the roof structure. An extensive system of pipes or ducts connecting the solar collectors to the storage tank and the storage tank to the heating system must also be accommodated. It is important, therefore, that proper allowance is made for the impact of solar equipment on the building components.

If a solar system is considered after the house is designed and partially built, location of the solar equipment, ducts, pipes, etc., may be a problem. Further, details of floor or roof loading capabilities may be overlooked. Experience with solar systems is limited, and little is known about the construction

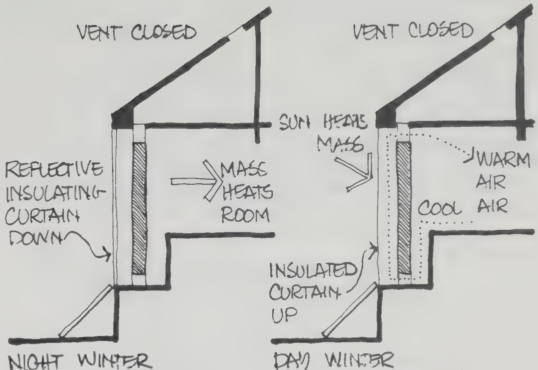


FIGURE 5·23 TROMBE WALL (WINTER OPERATION)

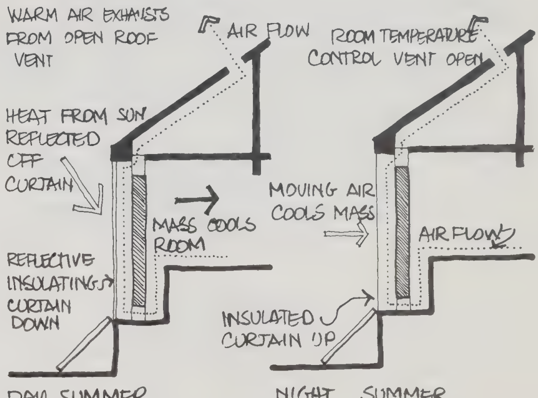


FIGURE 5·24 TROMBE WALL (SUMMER OPERATION)

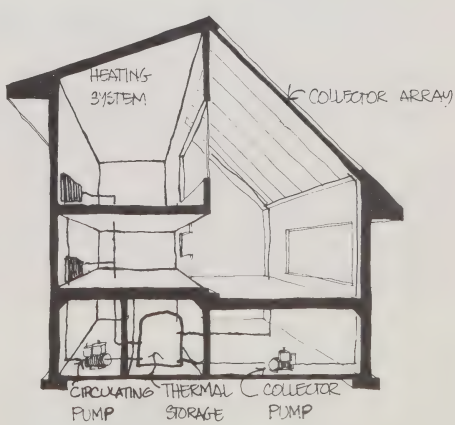


FIGURE 5·25
TYPICAL SOLAR HEATING SYSTEM

problems that may arise. Solar heating systems should only be used when their installation has been carefully planned from the outset.

Installation of a solar system should not affect the sizing or installation of standard heating equipment. Solar systems are rarely capable of supplying 100% of the heating requirements, because of problems that require a complete shutdown of the system are not uncommon. It is essential, therefore, that a complete auxiliary heating system be installed in addition to any solar system.

5.6.6 Active Solar Swimming Pool Heating System
The major source of heat loss from an outdoor swimming pool is evaporation of the water. Insulation blankets that cover the pool during periods when it is not in use should be used on all outdoor swimming pools, regardless of the type of heating system used.

Prefabricated solar heating systems are available that will replace the standard swimming pool heaters using fossil fuels (Figure 5.26). Pool water is circulated through the water filtration equipment to the solar collectors where it is warmed and returned to the swimming pool. These solar heating systems are supplied and installed by the maufacturer's representative at an average cost of $64/m² of collector. A typical system would require approximately 30 square metres of collector. The operating season for the average outdoor pool runs from May 15 to Sepember 15. During this period, the solar system should be able to provide 100% of the pool's heating needs if an insulation blanket is used. The payback period for a solar swimming pool heating system in place of a conventional pool heater is between 3 and 7 years.

The solar system should be installed by the manufacturer's representative to ensure that it will function properly and not damage either the house or the swimming pool equipment.

5.7 Summer Cooling Through Ventilation
This section examines the use of an attic exhaust fan as an alternative to a mechanical air conditioner for summer cooling.

5.7.1 Recommendations

- Consider provision of an attic exhaust fan in lieu of a mechanical air conditioning system to offset summer cooling need.
- Provide insulated **weatherstripped** lid for exhaust fan to be installed at the onset of the heating season.
- Wire fan to convenient wall mounted switch.
- Provide openings in soffits, gable or roof which will have sufficient free area to permit free passage of exhaust air.

5.7.2 Exhaust Fans
The use of mechanical refrigeration machines to provide air conditioning within a house during the summer has become common in recent years, but the capital and operating costs of such equipment has promoted a search for alternative ways to cool a home during hot weather. Tighter construction and improved

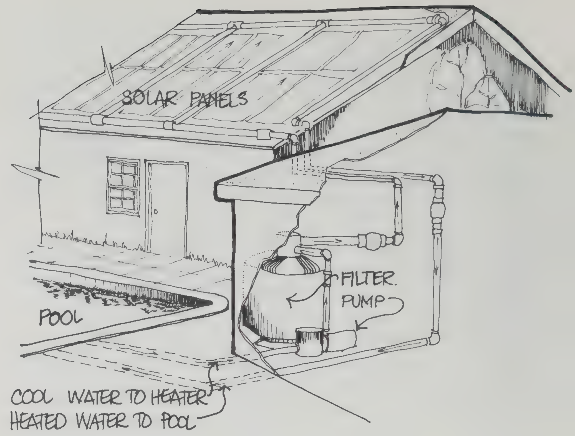


FIGURE 5·26
SOLAR SWIMMING POOL HEATING SYSTEM

insulation will do much to reduce the need for mechanical cooling. A high capacity exhaust fan, however, can improve the ventilation in the house and reduce nighttime temperatures by bringing in cooler outside air. During the day the house will generally be cooler than outdoors, so the exhaust fan will not be needed, but if indoor temperatures reach 28°C, increased air movement will improve the indoor climate. Some of the heat comes from the high temperature in the attic being radiated through the ceiling to the rooms below (Figure 5.27). Although high insulation levels there will minimize this problem, an exhaust fan will also help by lowering the air temperature in the attic.

It is obvious that during extended hot spells where nighttime temperatures are not much lower than daytime temperatures, night cooling of the house is not possible by ventilation alone. At the very least, however, an attic exhaust fan will prevent the house temperature from rising noticeably above the outdoor temperature, and will also provide air movement throughout the house.

The exhaust fan should be located in the attic for the reasons given above, and should be capable of exhausting the entire air volume of the house at least once every 30 minutes. The most convenient location for the fan is in the gable ends. If this is not possible, the fan may be mounted in the attic access hatch during the summer. In either case the fan should be fitted with a weatherstripped lid for the wintertime. If the fan is mounted in the attic access hatch, the hatch lid must also be insulated. See Subsection 3.1.2 and Figure 4.8 for suggested installation details.

The fan should be wired to a convenient wall-mounted switch to permit ready operation of the fan by the occupant.

If the fan is located in the access hatch, sufficient openings in soffits, gables or roof must be provided to permit escape of air. If soffit vents are used, careful attention is required to ensure that insulation does not cover openings. See Subsection 4.2.6.

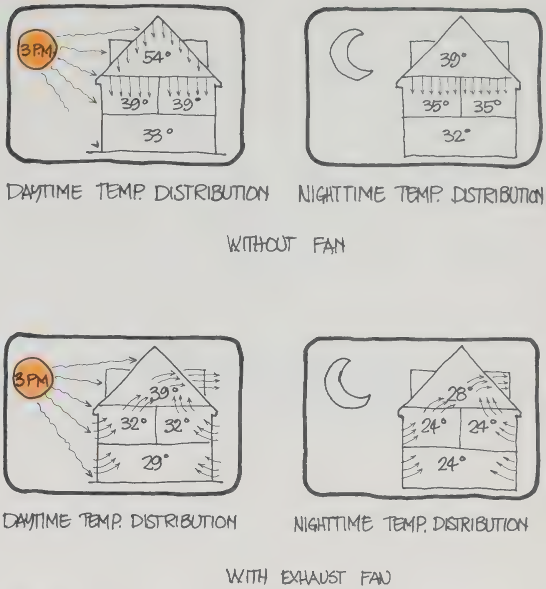


FIGURE 5.27
SUMMER VENTILATION

Section 6
Domestic Hot Water Heating

6.1 Domestic Hot Water

This section examines means for conserving hot water, sizing of the storage tank, alternative storage tank designs, and solar heating of domestic hot water.

6.1.1 Recommendations

Consumption and Conservation

- Provide restricted flow fittings on all lavatory faucets and shower heads.
- Provide an insulated heat trap on the discharge piping of the hot water tank.

Sizing Principles

- For a dwelling with 3 bedrooms or less, provide a 0.18 m^3 storage tank with a minimum heater capacity of 4 kW.
- For a dwelling with 4 bedrooms, provide a 0.27 m^3 storage tank with a minimum heater capacity of 6 kW.
- For dwellings containing more than 4 bedrooms, consider providing more than one hot water tank.
- Locate the domestic hot water tank as close as possible to the fixtures being served.

Electric Hot Water Tanks

- Insulate electric domestic hot water tanks with a minimum of 2.54 cm extra fiberglass jacket insulation.
- Set thermostat at 50°C.

Gas Hot Water Tanks

- Set thermostat at 50°C.
- Install a tank that has increased flue baffling to improve heat transfer.

Solar Hot Water Heating System

- If a solar heating system for domestic hot water is to be provided, obtain manufacturer's and designer's recommendations before proceeding with the installation.
- If a number of identical houses are to be fitted with solar hot water heating systems, ask manufacturers to supply prefabricated systems to suit the specific requirements.
- Employ the services of a contractor with field experience in the construction of solar heating systems.

6.1.2 Consumption and Conservation

The average family of four consumes 270 litres of hot water each day. An estimate of consumption by activity is given in Table 6.1.

Table 6.1 shows that hot water consumption in bathroom showers, and kitchen and bathroom sinks accounts for over 35 percent of the total hot water consumed.

Flow restricting devices may be installed directly into fittings to reduce the flow rate of faucets and showers. For faucets delivering between 14 and 18 litres of water

Table 6.1
Daily Water Consumption for a Family of Four*

Activity	D H W Consumption Litres
Dishwashing	30
Cooking	–
Kitchen Sink	25
Laundry	135
Showers and Bath	53
Bathroom Sink	27
Toilet	–
TOTAL	270

* Derived from Energy Efficient Home Operation Program by Canadian Electrical Association.

Table 6.2
Options for Reduced Domestic Hot Water Consumption

Conservation Device		Annual Energy* Savings GJ ($)	Cost $	Payback Yrs
Shower:	Flow Restrictor	3-5 ($ 22-15)	3-4	Under 1
	Adjustable Volume Control	3-4 ($ 22-15)	8-12	Under 1
Faucets:	Flow Restrictor	1-2 ($ 7-6)	1-3	Under 1
	Restrictor Aerator	1-2 ($ 7-6)	5-7	1
	Spray Tap	1-2 ($ 7-6)	8-10	1-2

*Annual energy savings will depend on annual consumption. The left hand column assumes electric water heaters and the right hand column assumes gas water heaters.

Table 6.3
Options for Reducing Energy Consumption in Electric Domestic Hot Water Heaters

Option	Availability	Annual Energy Savings GJ ($)	Cost $	Payback Yrs
2.54 cm extra fibreglass jacket insulation	Field applied	0.5 ($ 4)	6	2
Thermostat Setback 60°C to 50°C	Field set	1 ($ 7)	N/A	Immediate

a minute, flow restrictors could reduce the flow to 5-8 litres per minute while maintaining satisfactory performance.

Another method is installing restrictor aerators in kitchen and bathroom sinks to reduce splashing. This also reduces the flow rate to about 3 litres per minute by introducing air bubbles into the stream of water. Spray taps do not aerate the water, but restrict the flow to 4 or 5 litres per minute by delivering it in a broad pattern of droplets.

Special showerheads with adjustable volume control are available for a small additional cost. Table 6.2 shows the relative annual savings from each of these devices.

A major source of heat loss occurs in the first 1.5 metres of hot water piping connected to the tank. Natural convection circulates the water from the tank into the discharge pipe where it is cooled by the surrounding air. Insulating this length of pipe will only cause the water to travel farther before it cools. Use of a 'heat trap' will retard convective water losses by preventing natural convection from taking place (Figure 6.1).

The capital cost of installing such a trap is approximately $10. With a first year savings of $3, the heat trap pays for itself in about 3 years.

6.1.3 Sizing Principles

Domestic hot water tanks are available in two common sizes, 0.18 m³ and 0.27 m³. The water is heated by electric resistance elements or gas burners which come in a wide range of sizes. The size of heater needed depends on the occupants' habits. Not only must the consumption be known but also the time at which the water is consumed. Recommended tank volumes and heater capacities are provided in Subsection 6.1.1.

6.1.4 Electric Hot Water Tanks

Electric water heaters operate at approximately 83 percent annual efficiency. The transfer of electric energy to the water as heat is 100 percent efficient, but 14 percent of this heat is lost through the insulated tank wall. Standard heaters are insulated with 5 cm of fiberglass insulation to meet the standby heat loss standard established by CSA-191. Additional jacket insulation may be fitted to the tank (Figure 6.2), but must not be placed over access covers to water heater controls or over house wiring connection boxes.

Water heaters are equipped with thermostats controlling heater operation to maintain the desired water temperature. It has been common practice to set these thermostats at 60°C. Reduction of the thermostat setting to 50°C will not affect occupant comfort but will reduce standby losses through the insulated jacket.

Table 6.3 summarizes these options.

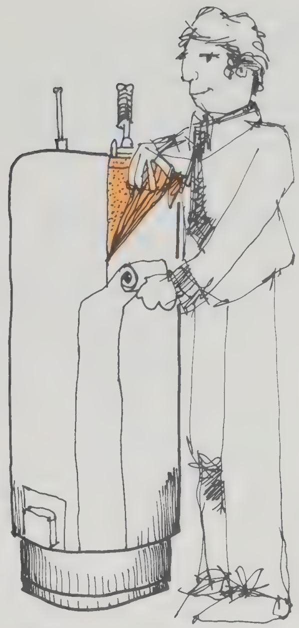


FIGURE 6·1

INSTALLATION OF JACKET INSULATION

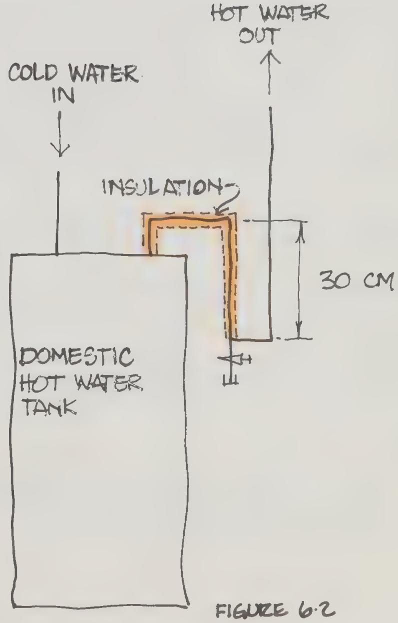


FIGURE 6·2

INSULATED HEAT TRAP

6.1.5 Gas Hot Water Tanks

The annual efficiency of a gas water heater is approximately 50 percent. About 12 percent of the fuel energy input is lost as heat conducted through the tank walls and insulating jacket; approximately 3 percent is lost in the hot water line during standby, and the remaining 35 percent is lost up the flue, in the form of hot combustion gases.

As with electric water heaters, setback of the thermostat to 50°C will reduce undesired heat losses.

Gas water heaters with increased flue baffling to promote better heat transfer from the hot combustion gases to the water will lose less heat up the flue.

Table 6.4 summarizes these options.

6.1.6 Solar Hot Water Heating Systems

There are two basic types of solar water heating systems in use. The first of these is a closed loop system, usually containing an antifreeze fluid. This is circulated through the solar collectors, where it is warmed, and then to a heat exchanger where it warms the domestic hot water (Figure 6.3). The second type is a drain-down system in which the water is drained out of the solar collectors during periods of inactivity to prevent freezing. As with the closed loop system, water is circulated through the solar collectors where it is warmed and then to the storage tank. Domestic cold water is heated by passing through a heat exchanger located in the storage tank (Figure 6.4).

At present, solar heating systems for domestic hot water cost approximately $430 to $650 per square metre of solar collector to install, including solar collectors, solar thermal storage tank, piping, pumps, controls, and labour. The average house would require between 4.5 and 11 square metres of solar collector. Such systems have a payback period ranging from 18 to 30 years.

Only experienced designers and contractors should be retained to install a solar heating system.

Manufacturers offer 'packaged' solar domestic hot water heating systems that come complete with solar collectors, storage tanks, controls, valves, etc. If a system is required for a number of identical houses, manufacturers are usually willing to supply a custom-designed system to suit the specific requirements.

Caution:

- If fluids other than water are being circulated through the solar collectors, check to ensure that the system will comply with local plumbing codes, and not pose a health hazard.

Table 6.4
Options for Reducing Energy Consumption in Gas Domestic Hot Water Heaters

Option	Availability	Annual Energy Savings* GJ ($)	Cost $	Payback Yrs
Thermostat Setback 60°C to 50°C	Field Set	1 ($ 3)	N/A	Immediate
Increased Flue Baffling	Factory Installed	1 ($ 3)	N/A	Immediate

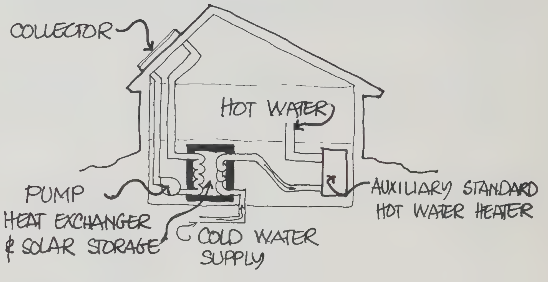


FIGURE 6·3
CLOSED LOOP SOLAR DOMESTIC HOT WATER SYSTEM

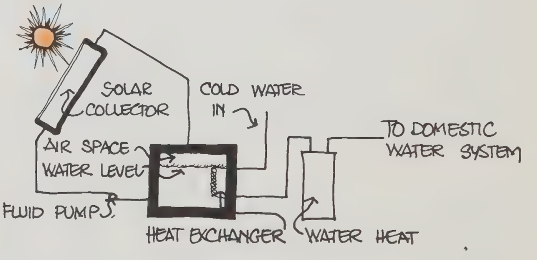


FIGURE 6·4
DRAIN DOWN SOLAR DOMESTIC HOT WATER SYSTEM WITH HEAT EXCHANGER

Section 7
Lighting and Appliances

7.1 Lighting and Appliances

This section examines the types and locations of lighting fixtures that will reduce the energy consumption of a house. Guidelines are provided for selection of energy efficient appliances.

7.1.1 Recommendations

Lighting

- Use fluorescent lighting instead of incandescent lighting wherever possible.
- Locate lights to illuminate specific areas. Indirect lighting should be avoided.
- Use wall-mounted switching for all lights.

Appliances

- Choose appliances that make the most efficient use of their energy consumption.
- Use appliances that are just large enough to handle the loads imposed.

7.1.2 Lighting

Fluorescent lamps are more efficient than incandescent bulbs in converting electrical energy to light, and should be used wherever possible. They produce three to four times as much light for the same energy rating as incandescents, and last twice as long. The most common sizes of fluorescent light used in residential construction are the 20-watt and 40-watt lamps.

In utility areas and workshops, the Standard Cool White lamp is recommended. For living areas, the more attractive Warm White lamp is preferred.

Fluorescent lighting fixtures should be shielded with plastic or glass lenses that reduce glare. These can be built into wall brackets (Figure 7.1), above counter areas (Figure 7.2), and beside the bathroom vanity mirror (Figure 7.3).

Light fixtures should be located as close to the point of use as possible (Figure 7.3). To encourage the occupant to turn lights off in unoccupied areas, each fixture should be provided with a convenient wall-mounted switch.

To promote lower light intensities, choose interior colour schemes that provide high reflectance values. Table 7.1 gives the reflectance of various building components recommended by Ontario Hydro.

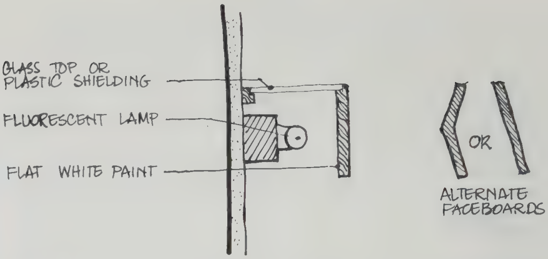


FIGURE 7·1 FLUORESCENT LAMP WITH WALL BRACKET

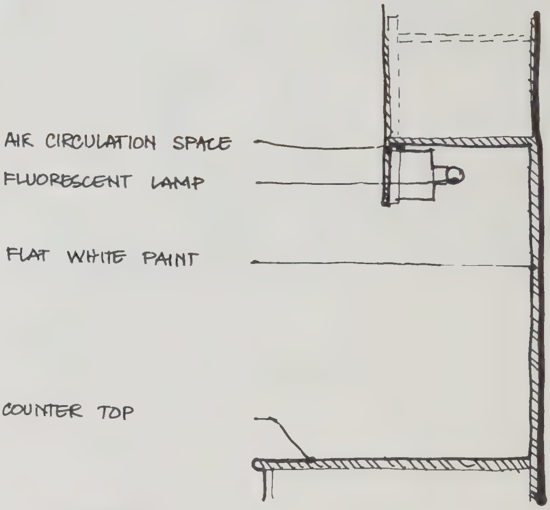


FIGURE 7·2

FLUORESCENT LAMP ABOVE COUNTER

Table 7.1
Interior Reflectance Values*

Surface	Reflectance Value (%)
Ceiling	80-90
Walls	40-60
Floors	25-45 (Typical)
Furniture	20-40 (Typical)

*These values can be provided by paint manufacturers.

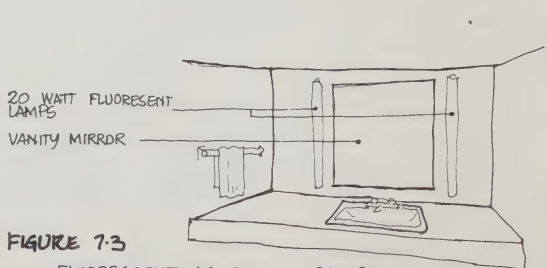


FIGURE 7·3

FLUORESCENT LAMPS IN BATHROOM

Although fluorescent fixtures and lamps are more costly than incandescents of equal wattage, their superior illumination and durability make them four times more economical. For lamps of equal wattage, the fluorescent light system will pay for itself within 3,100 hours of operations (at electricity rates of 2.7¢/kWh). Table 7.2 shows payback period for different frequencies of usage.

7.1.3 Appliances

Appliances vary significantly in their energy requirements. The major household appliances and their estimated monthly consumption are shown in Table 7.3.

It is important to realize that similar products made by different manufacturers may vary widely in their energy consumption. Table 7.4 provides a sample comparison for refrigerators. It is interesting to note that an automatic defrost refrigerator may be more efficient than some manual defrost refrigerators.

Consumer and Corporate Affairs Canada, through the Canadian Standards Association, is testing appliances for their energy consumption and affixing labels (Figure 7.4) that allow the purchaser to compare the efficiency of different appliances. Provision of the smallest appliance capable of handling the loads will almost certainly save both money and energy.

Air conditioners and water heaters are discussed in detail in Subsections 5.4 and 6.1 respectively.

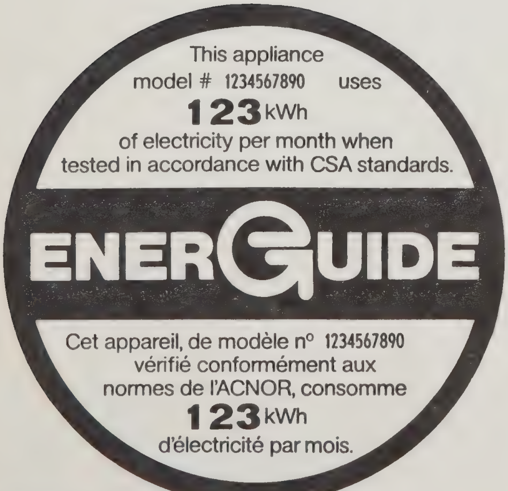


FIGURE 7·4

Table 7.2
Payback Periods for the Use of Fluorescent Lamps Instead of Incandescents

Hours of Use/day	Payback Period* Years
3	2-8
6	1-4
9	under 1

* For equal wattage fixtures.

Table 7.3
Monthly Consumption of Major Household Appliances

Appliance	Average Wattages watts	Monthly Consumption kWh	Monthly Cost* $
Food Freezer (non frost free 0.43 m^3)	335	75	1.98
Food Freezer (frost free 0.43 m^3)	425	90	2.38
Refrigerator Freezer (non frost free 0.34 m^3)	300	100	2.64
Refrigerator Freezer (frost free 0.34 m^3)	500	150	3.96
Range	12,500	100	2.64
Dishwasher	1,300	18	0.48
Clothes Washer	500	8	0.21
Clothes Dryer	4,800	80	2.11
Water Heater	4,500	500	13.20
Room Air Conditioner (6.3 MJ/hr)	935	60-400	1.52-10.56 (per season)
Room Air Conditioner (9.5 MJ/hr)	1,400	90-600	2.38-15.84 (per season)

*Based on an average 1979 cost for electricity of 2.7 cents per kWh.

Table 7.4
Monthly Energy Consumption for Three Refrigerator Types*

Refrigerator Type	Volume m^3	Monthly Energy Consumption** kWh	Consumption/Volume kWh/m^3
Automatic Defrost	0.48	118	246
	0.49	177	361
Semi-automatic Defrost	0.48	79	165
	0.38	105	276
Manual Defrost	0.37	70	189
	0.40	102	255

**Models chosen, give a high and low range.
*The above table is derived from the 1979 Energy Guide Directory of Refrigerators (Consumer and Corporate Affairs Canada, and Canadian Standards Association).

Section 8
Energy Efficiency In The Complete Dwelling

Previous sections of the Guide have reviewed energy conservation options for the building shell, space heating, domestic hot water heating and lighting. The purpose of this section is to tell the builder

- how to select the most suitable set of options considering his particular circumstances of location and construction costs

- what overall approaches may be taken to combine the options in the complete dwelling.

The section presents this information and illustrates purchase price implications for four dwelling types.

8.1 Recommendations

The following recommendations deal with

1. how to select options
2. the focused approach, which concentrates on those building elements which are costly to upgrade after construction is complete, and
3. the balanced approach, which provides improved energy efficiency at about the same level of cost effectiveness for all main building elements.

8.1.1 Selecting the Options

- Select a range of building element improvements that you think would be desirable for your market. This can be done either by selecting options directly from Sections 4, 5, 6, 7, or by developing others. Use suggestions in Subsection 8.2 for developing cost and payback information applicable to your specific project.

- Calculate how much each of these options will add to the price of the house.

- If you judge the price increase to be acceptable in your market, calculate the payback of each improvement either by using data in the Guide (if you are selecting options from the Guide) according to steps suggested in 8.2, or by using Appendix A if you are considering options not shown in the Guide.

- Check the results to make sure the price increase and the payback period are acceptable to your target market (see Section 9), then decide which options to use and whether to use the focused or balanced approach to combining them.

8.1.2 Focused Approach to Combining Options

- Building plans and designs incorporating some of the suggestions for internal layout, building form, and site planning discussed in Section 2 could be gradually worked in as designs are modified to suit lot sizes and meet other marketing requirements. These need not involve a cost premium.

- Using the estimated acceptable price premium, provide for the highest affordable performance level in construction of the exterior walls, and in the furnace and other mechanical and electrical equipment not easily improved after construction is completed. Consider upgrading windows and doors if usual installations have low performance compared with those discussed in Subsections 4.8, 4.9.

- Design the basement and attic to simplify the addition of more insulation: provide at least 500 mm clearance between basement walls and the furnace, pipes, hot water heater, and laundry equipment; and provide for attic accessibility and edge baffles (see Subsection 4.6) to allow for added insulation.

- Provide options for improving the performance of other elements. These options should have about the same payback period as the basic improvements to the external walls.

- If optional improvements are not selected at the time of construction or sale, provide the purchaser with general advice on how to install them later.

8.1.3 Balanced Approach to Combining Options

- Start by modifying building plans and designs to include the recommendations for internal layout, building form and site planning in Section 2.

- Using these plans, upgrade standard practice to include the full range of construction options suggested in the earlier sections. These will include:

  – greater attention to installing the air/vapour barrier and insulation (Section 4),

  – higher levels of insulation (Section 4) for all parts of the building shell involving a range of improvements with approximately the same payback period,

  – methods to control ventilation and moisture control (Section 3),

  – improved mechanical and electrical equipment (Section 5, 6, and 7).

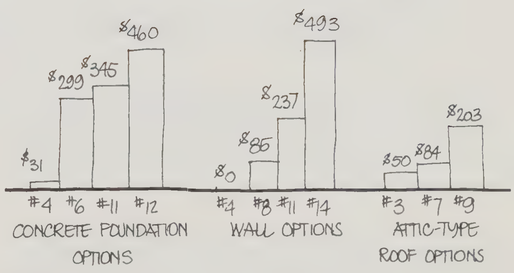
8.2 Options for the Complete Dwelling

A wide range of energy conservation options have been presented and evaluated in the Guide; builders must select the ones most suited to their own conditions.

The builder can select energy conservation options from those ranked best in the Guide, or develop his own construction improvements. Selection will also depend on the available labour and materials, as well as market preferences.

However, the options must be evaluated further in terms of actual costs and effectiveness in terms of payback as a means of ensuring buyer acceptance. As an aid to selecting options for the main building elements, Figure 8.1 illustrates options having a range of cost premiums related to the base case house described in Subsection 4.2. The builder must first confirm the purchase price premium for each of the improvements.

If the results of this indicate that the extra required price for some or all of the options might be acceptable to the market, the builder should then estimate the payback period for each option to provide additional sales information.



NOTES

1. BUILDERS SHOULD CONSIDER ADDING SPARK IGNITION GAS FURNACES ($100) IN ADDITION TO SELECTING OPTIONS FOR THE ABOVE ELEMENTS.
2. COST PREMIUMS ARE FOR THE BASE CASE HOUSE (SUBSECTION 4.2.2).
3. OPTIONS SELECTED ON BASIS OF HAVING COMPARATIVELY LOW PRICE PREMIUM FOR R VALUE APPLIED.

FIGURE 8.1
SELECTED OPTIONS FOR MAJOR BUILDING ELEMENTS REPRESENTING A RANGE OF PRICE PREMIUMS

If the conservation options are chosen directly from the Guide, an indication of payback period in years can be calculated using information supplied with those options. To do this, the builder should know the degree days of his area. He must select the option information in the Guide for a consistent degree day value and for the same energy source proposed to heat the builder's dwelling. The payback period in years can be quickly calculated in two steps, using an energy conservation option for external walls as an illustration:

1. First calculate annual energy savings (in dollars) for the wall in the builder's dwelling by A x B x C x D

   where

   A = Annual energy savings of wall option from table in Guide

   $$B = \frac{\text{Degree days of location of builder's dwelling}}{\text{Degree days of wall option from the Guide}}$$

   $$C = \frac{\text{Fuel cost at location of builder's dwelling}}{\text{Fuel cost used in the Guide}}$$

   $$D = \frac{\text{External wall area of builder's dwelling}}{\text{External wall area of base case house used in the Guide}}$$

2. Then calculate payback period from the selected option under builder's conditions by E x F x G

   where

   E = Payback of wall option as from table in Guide

   $$F = \frac{\text{Annual energy savings of wall option from table in Guide}}{\text{Annual energy saving of wall option in builder's dwelling (calculated above)}}$$

   $$G = \frac{\text{Construction Premium of wall option in builder's dwelling}}{\text{Construction premium of wall option from table in the Guide}}$$

This method assumes that the insulation level of conventional construction in the builder's location is equivalent to the base case house used in the Guide. Even if this is not so, the above calculation will provide a good indication of payback period.

If the builder wishes to select an energy conservation improvement that is not in the Guide, then he should carry out the more detailed calculations for each element as indicated in Appendix A.

The builder will then wish to review the costs and payback period for options for each of the elements and select those which he feels will best suit his market. At the same time he can decide whether he wants to upgrade just one or two elements such as walls and furnaces, or whether he feels his market will accept the price premium for improvements in other elements as well, such as ceilings and foundation walls. Logical approaches to making this decision are described below.

8.3 Combining the options

There are two basic approaches to combining the various options: the focused approach and the balanced approach.

8.3.1 The Focused Approach

The focused approach concentrates on the most effective improvements. Using this approach the most logical place to provide energy-saving construction features is where they would be difficult or costly to put in later. This includes exterior walls and upgraded space heating or domestic hot water heating equipment. Other energy conservation options should be included if they are cost effective and do not increase the dwelling purchase price beyond buyer acceptance.

This approach may be justified when a high level of insulation in all building elements (measured in terms of payback period) will increase the initial cost of the house more than buyers will accept. Or when the most effective way of reaching a high degree of energy efficiency (especially in lower cost housing) is to provide a high level of performance in some elements, and let the homeowner take advantage of potential government programs and his 'do-it-yourself' skills to bring other building elements to the same level. A logical marketing strategy, however, would involve providing upgrading of these other building elements as an option at the time of purchase (see Section 9).

8.3.2 The Balanced Approach

In the balanced approach, a number of energy-saving features with similar payback periods are provided. The degree (and cost) of upgrading can be varied to suit the market – a payback period of as little as three to five years, say, in the lower price market, and eight to ten years, or even longer, for higher priced housing (see Section 9). The payback periods for mechanical and electrical equipment may vary from those of other building elements, even in the balanced approach due to the different nature of these elements (see Sections 5, 6, and 7).

8.4 Price Premium by Dwelling Unit Type

An important factor in introducing energy efficient features is the increase in purchase price. This will vary according to the type and size of the dwelling.

It is useful to review the effect on total price caused by providing a range of energy conservation options. The following information illustrates price increases for:

a) the focused approach concentrating on exterior walls and furnace

b) the balanced approach to the main building elements – basement walls, exterior walls, ceilings, and furnace.

These price calculations are based on standard builder's plans for four dwelling types:

- bungalow
- two-storey detached
- semi-detached
- row house.

The price premiums are based on increases over the Ontario Building Code 1979 requirements. Construction costs for 1979 in Southern Ontario are used in the calculations.

Two sets of improvements are shown. The first set has a payback period of 12-13 years. The second has a payback period of 18-23 years. Both provide high insulation values for foundation walls, exterior walls and ceilings. The gas furnace is upgraded with spark ignition and has a payback of about six years. See Tables 8.1, 8.2, 8.3, 8.4 for price premiums and unit plans. The option numbers indicated refer to those found in appropriate tables in Section 4.

A comparison of the results shows that the row house has the lowest price premium for both payback ranges while the 2-storey detached house has the highest price premium for both payback ranges. This is due to the relatively larger wall area in the latter dwelling type.

In these examples the cost premium for the focused approach ranges from $190 to $863. The cost premium for the balanced approach ranges from $244 to $1,363.

Assuming Southern Ontario purchase prices of $50,000-$60,000 for the bungalow, $80,000-$90,000 for the 2-storey detached house, $50,000-$55,000 for the semi-detached unit, and $45,000-$50,000 for the row house, the premium for the more costly balanced approach is about 1-2% of the total purchase price of the dwelling. In these examples the price premium for the focused approach is about ½ to ¾ that of the balanced approach.

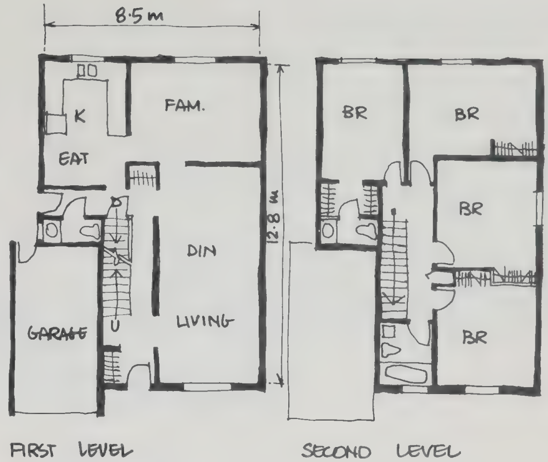
Table 8.1
Bungalow

Building Element	Payback Range 1			Payback Range 2		
	Option #	Payback Period yrs	Price Premium $	Option #	Payback Period yrs	Price Premium $
Basement	5	12	98	8	23	361
External Walls	6	13	250	12	18	478
Ceiling	3	13	79	5	22	188
Furnace		6	100		6	100
Price premium for balanced approach (all elements)			527			1127
Price premium for focussed approach (external walls, furnace only)			350			578

Bungalow
area: 99 m²

Table 8.2
Two-storey Detached

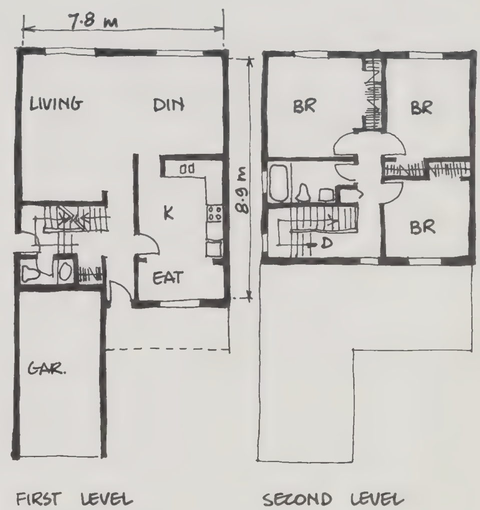
Building Element	Payback Range 1			Payback Range 2		
	Option #	Payback Period yrs	Price Premium $	Option #	Payback Period yrs	Price Premium $
Basement	5	12	92	8	23	337
External Walls	6	13	399	12	18	763
Ceiling	3	13	69	5	22	163
Furnace		6	100		6	100
Price premium for balanced approach (all elements)			660			1363
Price premium for focussed approach (external walls, furnace only)			499			863



Two-storey Detached
area: 172 m²

Table 8.3
Semi-detached

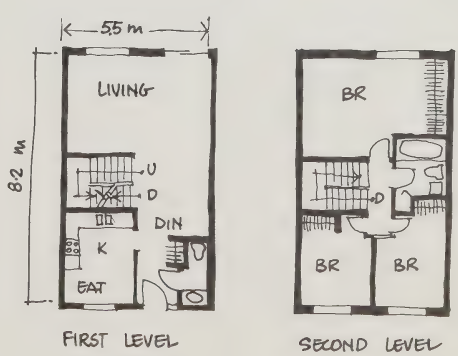
Building Element	Payback Range 1			Payback Range 2		
	Option #	Payback Period yrs	Price Premium $	Option #	Payback Period yrs	Price Premium $
Basement	5	12	53	8	23	196
External Walls	6	13	215	12	18	411
Ceiling	3	13	52	5	22	123
Furnace		6	100		6	100
Price premium for balanced approach (all elements)			420			830
Price premium for focussed approach (external walls, furnace only)			315			511



Semi-detached
area: 119 m²

Table 8.4
Row House

Building Element	Payback Range 1			Payback Range 2		
	Option #	Payback Period yrs	Price Premium $	Option #	Payback Period yrs	Price Premium $
Basement	5	12	13	8	23	46
External Walls	6	13	90	12	18	172
Ceiling	3	13	41	5	22	97
Furnace		6	100		6	100
Price premium for balanced approach (all elements)			244			415
Price premium for focussed approach (external walls, furnace only)			190			272



Row House
area: 101 m²

Section 9
Marketing Energy Conservation Features In New Housing

The purpose of this section is to review various marketing principles and recommend approaches that the builder can take to help him market the energy efficient features that he has incorporated in his dwellings.

9.1 Broad Recommendations

- After making the effort to determine what energy conservation features to provide, publicize them strongly and take the time to explain them to prospective buyers.
- Remind prospective buyers that energy conservation features mean immediate real savings in energy costs which can ultimately result in net savings in ownership costs.
- The focused approach is the most flexible way of providing energy efficiency because builders can provide optional features such as adding more ceiling insulation at the time of purchase.
- Builders should make every effort to persuade lending agencies that the extra purchase price for energy conservation features should be included in the allowable mortgage amount.
- Builders should consider three main markets when deciding on what approach to take in offering energy conservation features:
    - first-time buyers
    - move-up buyers
    - move-down buyers

9.2 General Marketing Principles

Earlier sections have indicated that there is an initial price premium for most of the energy conservation options. Because the home purchaser must decide what price he is prepared to pay for energy efficiency, the analysis of options in this Guide has considered cost effectiveness in terms of how long it would take for the initial investment to be paid back in the form of energy savings.

Home buyers are interested in saving energy, but builders can encourage greater acceptance, and ultimately reduce the growth in energy demand, by promoting and providing improved construction.

Marketing energy conservation will also help to sell homes as buyers realize that energy efficiency

- pays increasing dividends as energy prices continue to rise, and
- improves resale value.

An understanding of these benefits can therefore be a strong incentive to purchase homes with energy saving features.

Experience in marketing of energy efficient features in housing has become more common in the last few years. A number of principles should be understood by the builder to help him organize his marketing approach.

- Housing type, location and price continue to be the primary factors for dwelling selection. Energy efficiency and other features are clearly considered less important.

- Buyer awareness of the importance of energy conservation, particularly in the home, is increasing due to steadily rising fuel prices and predictions regarding the availability of domestic and foreign energy supplies.

  - Energy-saving options received the highest rating in a recent survey of home buyers in Western Canada, where heating costs are among the lowest in the country.

  - In the U.S., energy efficient homes are selling in a wide price range to all categories of buyers.

- Buyers of all ages and income ranges are interested in energy conservation features. Those at the lower income scale, however, are often reluctant to pay a premium for these features, because their major concern is being able to afford monthly mortgage payments for basic shelter. Builders should offset this concern in their marketing approach.

- The inside living space and appearance remain extremely important. Reduction of space and/or the quality of visible materials and finishes to offset any cost premium for energy-saving features may meet with buyer resistance. By considering the idea of payback period for energy efficient features it is not necessary to reduce floor area or quality.

- Buyers of the most expensive houses appear to be more energy conservation conscious and appear to accept higher costs for such features as part of the overall price.

- Three specific market sectors, first-time buyers, move-up buyers, and move-down buyers (see Subsection 9.3), vary in their degree of acceptance of energy efficient features.

These principles will continue to evolve as energy conservation increases in importance and as more buyers gain a greater knowledge and understanding of the value of energy efficiency.

9.3 Three Specific Market Sectors

While the addition of energy efficient features in builders' homes reduces operating costs, it generally increases the down payment and/or monthly mortgage payments, and that affects the market sectors mentioned in Subsection 9.2 and described in more detail below.[1]

1 Note that there may be variations within each of these market sectors, but in general terms their description is as indicated in 9.3.1, 9.3.2 and 9.3.3.

9.3.1 First-Time Buyers

First-time buyers are usually young couples with one or two young children. Both husband and wife may work, but if the wife works, daycare costs will reduce the total family income. Generally they cannot afford large carrying and operating costs. This group has little or no first-hand experience in operating and managing a dwelling unit.

They generally view their first purchase as a transitional step until such time (usually three to five years) as they can afford a more luxurious home in a more suitable location, and one that is large enough to raise older children. Their first home purchase must provide basic shelter and cannot contain too many extras, including costly energy efficient features with a long term payback. At the same time, this group would like improved energy conservation and reduced operating costs.

The builder can appeal to this market sector in the following ways:

- Provide them with a compact dwelling unit with simple form and internal layout features as described in Section. 2. These features need not involve any price increase.
- Offer basic upgrading of energy efficiency by concentrating the improvements in the exterior walls. Point out that this provides performance beyond code requirements. Indicate that the remaining areas of upgrading can be done easily later, in some cases as a 'do-it-yourself' project for the owner. Or offer upgrading of these features as optional extras to be built in during construction or added at the time of sale.
- In a highly competitive market where prices must be kept as low as possible, select energy efficiency features that will provide a three to five year payback, and explain the meaning of this to potential puchasers in relation to their likely period of ownership.
- In particular, note (where applicable[2]) that the reduction in yearly heating costs is greater than the increase in mortgage payments, and that this difference will continue to grow as fuel prices rise.

9.3.2 Move-Up Buyers

Move-up buyers are generally couples with older children. They have greater financial means that first-time buyers. The husband is at a higher career level than he was as a first-time buyer, and the wife may be able to work full-time with little or no daycare costs if the children are in school. More importantly, move-up buyers often have substantial equity from their previous home.

They anticipate staying in their new home at least until their children have grown up, often eight to ten years or longer. They want comfort, convenience and expect to pay for it, partly because the husband may have less time for 'do-it-yourself' projects. They have an understanding of the investment value of their home, and generally prefer large single family houses. Their experience with their first dwelling has taught them to appreciate the significance of operating costs and they

2 This applies only if the lender recognizes the extra prices of the conservation features by increasing the mortgage amount, and if the builder has selected cost-effective features.

will consider the benefits of a wide range of energy efficient features. Consistent with their anticipated length of time of ownership, they may be willing to consider a longer payback for these features (i.e, 8 to 10 years). Buyers of dwellings in the higher price ranges will be less concerned about payback and more interested in obtaining highest quality including high energy efficiency.

The builder can offer this group a much broader range of energy efficient options:

- Offer a very high level of energy efficiency. This may be in the form of the balanced approach as a total package, or it may consist of high performance exterior walls and a series of optional features.

- The buyers' anticipated length of time of ownership suggests that these dwellings should be provided with features beyond code requirements having a payback of eight to ten years (or longer for houses in the upper price range).

- Explain the payback concept, and, using Figure 1.3 as a guide, discuss how current energy costs may change over the next few years.

9.3.3 Move-Down Buyers

Move-down buyers are generally couples or individuals whose children have grown up and left home. This group does not generally expect its income to keep rising and wishes to avoid reducing capital saved. Move-down buyers have significant equity from previous home ownership.

This group, like the move-up buyers, also anticipate a relatively long stay in their home compared to first-time buyers. They also prefer comfort and convenience with the added advantage of lower operating costs and less maintenance work than the larger home they are leaving. This group is also very conscious of the housing unit as an investment. Their preference is for a smaller (but not necessarily cheaper) single family house, semi-detached unit, or row house. The idea of living on a relatively fixed income after retirement improves the likelihood of acceptance of energy conservation features. However, the move-down buyer may be less interested in 'do-it-yourself' energy efficiency improvements because of his increased age.

The builder can provide and sell these features as follows:

- Provide for a high level of energy efficient features in the overall home package, or build a high level of insulation into the exterior walls and offer upgrading of other elements as options. Point out the increased cost and effort of adding options at a later date.

- Select features with an eight to ten year payback (or longer if the buyer will accept).

- In contacts with potential buyers, try to relate the energy efficiency improvements to features of their large present home, to emphasize the savings of going to a more compact and efficient dwelling.

- Be prepared to comment on trends in the price of energy, and the importance of energy costs for home buyers with stable incomes.

- Point out the effect of the energy saving features on resale value.

Table 9.1 summarizes the alternative approaches for combining the options for all 3 market sectors.

9.4 GENERAL MARKETING APPROACHES

In addition to considering the three broad market sectors reviewed above, builders should take a variety of general marketing steps to sell energy efficient features.

9.4.1 Local Factors Affecting Energy Consumption

- Be aware of such information as degree days[3] in the local area, wind direction and speed, and frequency of periods of particulary cold weather.

- Be aware of local unit cost for the main sources of energy, availability, supply, and short term projected cost growth rates.

- Note the extent of publicity given in local news media and other sources available to potential buyers regarding rising energy costs, potential shortages, and other general energy predictions. It is against this background that buyers will be considering the extent they wish to invest in energy efficiency in their new home.

9.4.2 Buyer Characteristics

- Learn and understand the characteristics of the target market: age, income, family size, lifestyle, level of education.

- Relate these to the three main market sectors discussed above. Select the characteristics which energy efficient features must meet (for example, payback period, maximum dollar amount, appeal to various levels of understanding).

9.4.3 Other Marketing Experience

- Through local builders' associations, determine what the experience has been in the area with respect to introducing energy efficient features: what features, who is buying, estimated price premium, owner reaction after one or two heating seasons.

- Be aware of the same information on a regional/ national or North American level through periodicals for the housing industry, and builders' associations.

9.4.4 Selection of Features

- Consider the full range of energy efficient features including choice of dwelling unit type, internal layout, site planning, landscaping and building element details.

3 This information can be obtained in publication NRCC No. 15556 from
Division of Building Research
National Research Council of Canada
Ottawa, Ontario K1A 0R6

Table 9.1 Approaches for Combining Options for the Three Market Sectors

Approach	First-Time Buyers	Move-Up Buyers	Move-Down Buyers
Focused approach with advice for later improvements	•		
Focused approach with options for other elements at the time of construction/sale	•	•	•
Balanced approach		•	•

- Calculate the price premium over a similar dwelling which meets minimum requirements of the building code. Estimate payback range (Subsection 8.2.1 and Appendix A).

- Decide on whether to use the balanced approach, upgrading all major building elements to the same general payback length, or the focused approach, emphasizing elements not easily improved after construction, such as walls and space heating equipment. The focused approach should be combined with the option of upgrading the other elements at the time of construction or sale, or with suggestions for later improvments when the owner can afford it.

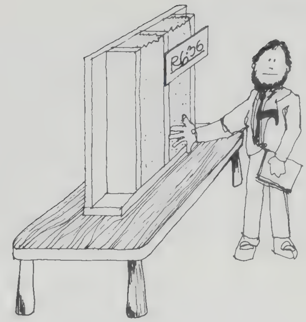


FIGURE 9.1

- Relate payback period to the appropriate market sector. At the upper end of the price range, cost premiums and payback time will not be as important as for the more modestly-priced home.

- In selecting energy efficient features, remember that the dwelling must first meet the basic needs and desires of the potential buyer. Do not rely on improvements to energy efficiency or other innovations to compensate for essentials that are not provided.

9.4.5 Presenting the Features

- Highlight the fact that the dwelling contains energy efficient features beyond requirements of the local or provincial building code.

- Emphasize that the dwelling form, materials and workmanship are based on what buyers have indicated they want.

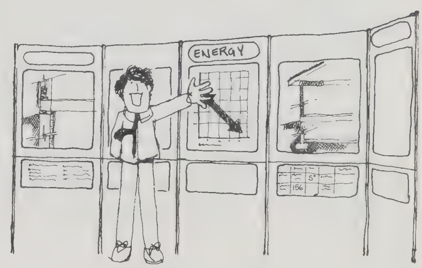


FIGURE 9.2

- If the optional approach is used, explain that the buyers have a choice in deciding what energy efficient features they wish to purchase, now, and what features they want to add later. Point out that the buyer will save money if he purchases all of the available options at the time of construction, as improvements contracted after are generally more costly.

- Provide mock-ups of some features: for example a wall section, or a ceiling section (Figure 9.1). These can be displayed in the model home or sales office. Use large labels attached to or near these features in model home. Or use display panels and large labelled diagrams to illustrate energy efficient features (Figures 9.2, 9.3). These can be displayed in the sale area and be included in promotional literature. In all cases note the fact that insulation materials have been accepted by CMHC.

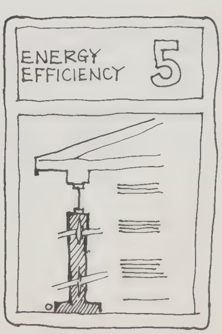


FIGURE 9.3

- Be prepared to explain what the features are, their functions, why they are important, and the concept of payback (if applicable). Also explain that the energy cost savings will continue long after the cost premium has been paid off, thereby making the home a good investment for the first buyer as well as subsequent buyers.

- Indicate how careful planning and design has resulted in improved building form, internal layout and site planning that helps reduce energy consumption at no additional cost to the buyer.

- Be sure that sales staff or real estate agents are familiar with the features, can point them out and explain them.

9.4.6 Owner's Manual

- To emphasize the serious study and research put into the design and construction, develop a home-owner's manual that relates specifically to the construction features being offered. This will also be the home-owner's guide to operation and maintenance, and will servie to instruct the occupants on how to achieve the most benefit from energy efficient features. It could also contain information on how to prolong the life of the home through timely and proper maintenance.

- This guide should contain such items as:
  - suggestions for habits which will ensure the highest level of energy efficiency
  - reminders on humidity control and winter ventilation
  - information on operating and servicing all major appliances, especially the space heating equipment and hot water heater
  - landscaping suggestions to reduce heat loss in winter and heat gain in summer
  - recommendations for maintenance of exterior and interior surfaces, and doors and windows
  - a suitable folder for the warranty, insurance policies, and a file pocket for keeping records on such items as energy costs, property taxes, insurance premiums, and mortgage payments
  - publications[4] by Energy, Mines and Resources Canada: 'The Billpayer's Guide to Furnace Servicing', '100 Ways to Save Energy in the Home', and 'Keeping the Heat In'.

9.4.7 Reaction of Potential Buyers and Purchasers

- Take the opportunity when talking with potential buyers to discuss their opinions, interests, and understanding related to the energy efficiency features, including the manner in which they are presented.

- Review reactions to the features with selected puchasers after occupancy through at least one heating season.

- Based on these findings, begin planning the next round of energy efficient features and the related marketing effort.

4 Use latest editions, modified to give up-to-date advice.

Appendices

APPENDIX A
HEAT LOSS AND PAYBACK CALCULATIONS FOR BUILDERS

This appendix provides data and a method which will permit builders to carry out their own calculations of annual heating costs and savings due to upgrading. This will allow the evaluation of options not included in this Guide. The method demonstrated in the following example is based on a number of simplifications and assumptions but is sufficiently accurate for the intended purposes.

In order to permit the evaluation of options not included in the Guide it is necessary to go to greater detail than has been presented thus far. For example it is necessary to calculate the reduction in R values due to heat loss through framing.

It is also necessary to deal separately with the below grade, above grade and header portions of the foundation walls rather than look at overall heat loss factors as was done (for comparision purposes) in Section 4.

In order to use this method the builder needs to know the following:

- dimensions of the house
- materials used in the base house and in the proposed upgraded house
- cost of the proposed upgrading
- local price of the relevant energy source
- degree days of the site[1]

A.1 WORKED EXAMPLE

For simplicity we will work with a two-storey detached house of simple rectangular shape with no insets or projections. Details of the house are shown below. The upgraded house will include improvements to the building shell as shown, and a spark ignition gas furnace. (Figure A.1)

OTHER GIVEN DATA: Storeys – 2
Plan Dimensions – 9.0m x 9.56m
Window Area in:

Basement	4.0m²
1st Storey Walls	12.0m²
2nd Storey Walls	8.0m²
Door Area	4.0m²
Heating	base case: gas furnace with conventional pilot light, upgraded house: spark ignition gas furnace
Stud Spacing	400mm o.c. 1st storey 600mm o.c. 2nd storey
Windows	double glazed – R 0.3
Doors	insulated steel – R 1.0
Air Change	assumed to be 0.3 air changes per hour both before and after upgrading
Location	Oshawa, Ontario 4130°C Degree-days
Cost of Gas	\$0.11/m³ \$0.003/megajoule

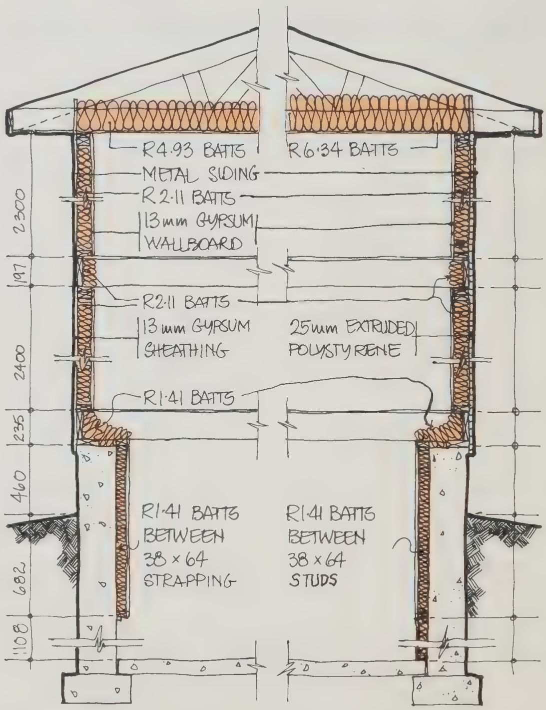


FIGURE A·1
BASE HOUSE UPGRADED HOUSE

[1] Degree-day values for 80 metropolitan areas and large urban centres across Canada are given in Table B1. Values for other locations can be found in *Climatic Information for Building Design in Canada,* Supplement No. 1 to the National Building Code, NRCC No. 15556, from Division of Building Research, National Research Council, Ottawa, K1A 0R6.

A.1.1 Step 1 – Calculate Areas

Perimeter = 2 × (9.0 + 9.56) = 37.12m
Ceiling Area = 9.0 × 9.56 = 86.04m²
2nd Storey Wall Area = 2.300 × 37.12 = 85.38
minus windows – 8.0
= 77.38m²

2nd Storey Floor Header Area = 0.197 × 37.12 = 7.31m²

1st Storey Wall Area = 2.400 × 37.12 = 89.09
minus windows – 12.0
minus doors – 4.0
= 73.09m²

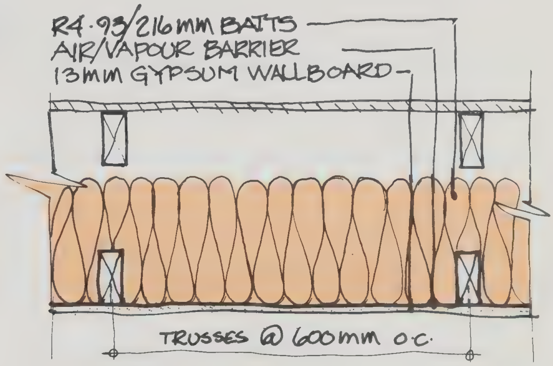
1st Storey Floor Header Area = 0.235 × 37.12 = 8.72m²

Above Grade Foundation Wall Area = 0.460 × 37.12 = 17.08
minus windows – 4.0
= 13.08m²

A.1.2 Step 2 – Calculate R Values

R values for individual materials are found in Table B.2. Rather than carry out all the repetitive calculations here, only examples are shown.

Base Case Ceiling:

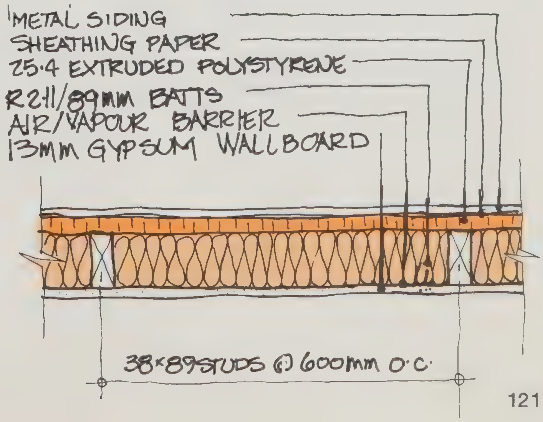


	R through insulation	R through truss bottom chord
Bottom air film	0.105	0.105
Gypsum 0.0062x13	0.081	0.081
Framing 0.0087x89	–	0.774
Insulation	4.930	$\frac{127}{216}$x 4.93 = 2.899
Top air film	0.030	0.030
	5.146	3.889

With framing at 600mm o.c., the framing represents about $\frac{38}{600} = 7\%$ of the area. For every 100m² of ceiling area, there would be 7m² with framing and 93m² without.

$$\text{Therefore adjusted } R = \frac{100}{\frac{93}{5.146} + \frac{7}{3.889}} = 5.03$$

Upgraded 2nd Storey Wall:

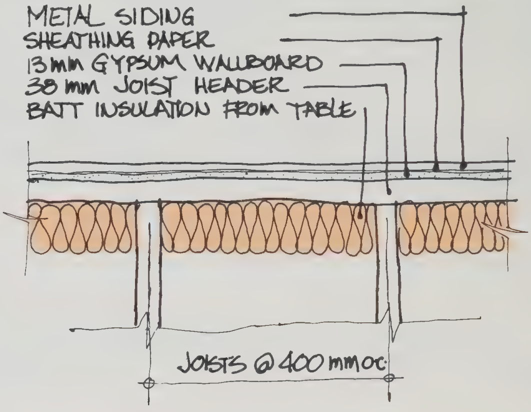


	R through insulation	R through studs
Outer air film	0.030	0.030
Metal siding	0.123	0.123
Sheathing paper	0.011	0.011
Extruded Polystyrene 0.0347x25.4 = 0.881	0.881	0.881
Batts	2.11	–
Framing 0.0087x89 = 0.774	–	0.774
Gypsum 0.0062x13 = 0.081	0.081	0.081
Inner air film	0.120	0.120
	3.356	2.020

For walls the percentage of framing is somewhat higher than for ceilings with the same framing spacing due to the presence of window and door framing, doubled studs at partition intersections, etc. With 600mm spacing, each 100m² of wall will have about 11m² with framing and 89m² without. With 400mm spacing, the proportions would be about 19m² and 81m² respectively.

Therefore adjusted R = $\dfrac{100}{\dfrac{89}{3.356} + \dfrac{11}{2.020}} = 3.13$

Base Case 2nd Storey Floor Header:



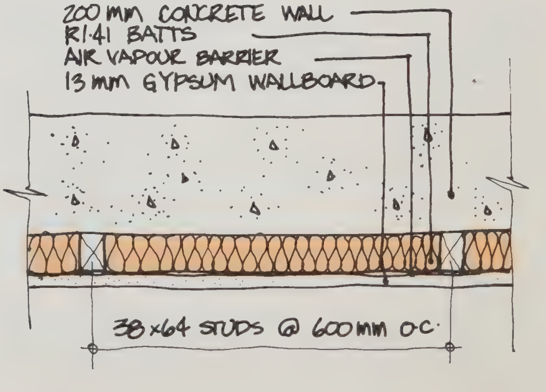
Heat loss through the header area is quite complicated and correcting for the interruption of the insulation by the joists can be quite tedious. The following table is therefore provided to relate the R value of the batts added to the header area to their final, adjusted value. It also makes some allowance for loss through the subfloor.

Table A.1 – Adjusted R Values For Joist Header Areas

R Value of Batt	Adjusted R Value
1.41	1.17
1.76	1.47
2.11	1.67
2.47	1.84
3.52	2.80
4.93	3.94

Outer air film	0.030
Metal siding	0.123
Sheathing paper	0.011
Gypsum 0.0062x13	0.081
Header 0.0087x38	0.331
Insulation (from table)	1.67
Inner air film	0.120
	2.366

Foundation Wall Above Grade:



	R through Insulation	R through Studs
Outer air film	0.030	0.030
Concrete 0.00045x200 = 0.090	0.090	0.090
Batts	1.41	–
Framing 0.0087x64 = 0.557	–	0.557
Gypsum 0.0062x13 = 0.081	0.081	0.081
Inner air film	0.120	0.120
	1.731	0.878

$$\text{Therefore adjusted R Value} = \frac{100}{\frac{89}{1.731} + \frac{11}{0.878}} = 1.56$$

Base Foundation Wall Below Grade:
Here, rather than an R value, we will work out a heat loss factor for a 1 metre wide vertical strip. This is similar to the factors given in Tables 4.1 and 4.2 but here it will apply to the below grade portion only.

From Figure B.2 for R1.41 added to 600mm below grade,
Heat Loss Factor = 0.67 w/°C – m
For 900mm below grade,
Heat Loss Factor = 0.58 w/°C – m
Interpolating, for 682mm below grade,
Heat Loss Factor = 0.65 w/°C – m

A.1.3 Step 3 – Calculate G Factors

The G factors represent overall heat loss factors (HLF). These are determined for conduction and convection (air change).

Conduction Through Building Shell
Using the procedures illustrated above all R values for both the base and upgraded houses can be calculated and tabulated as follows:

		Base House		Upgraded House	
	Area (m^2)	R (m^2 °C/W)	A/R (W/°C)	R (m^2 °C/W)	A/R (W/°C)
Ceiling	86.04	5.03	17.11	6.48	13.28
2nd Storey Walls	77.38	2.28	33.94	3.13	24.72
2nd Storey Header	7.31	2.37	3.08	3.17	2.31
1st Storey Walls	73.09	2.12	34.48	2.98	24.53
1st Storey Header	8.72	1.87	4.66	2.67	3.27
Above-grade Fdn.	13.08	1.56	8.38	1.56	8.38
Windows	24.00	0.30	80.00	0.30	80.00
Doors	4.00	1.00	4.00	1.00	4.00
	Perimeter (m)	HLF (W/°C-m)	Perimeter XHLF	HLF (W°C-m)	Perimeter XHLF
Below-grade Fdn.	37.12	0.65	24.13	0.44	16.33
TOTALS			209.78 W/°C		176.82 W/°C

Air Change
The house volume is approximately the sum of all the vertical dimensions in Figure A.1 multiplied by the plan area of the house; i.e.
$7.38 \times 9.0 \times 9.56 = 635\text{m}^3$

Therefore volume changed per hour = $635 \times 0.3 = 191\text{m}^3$
Each cubic metre of outside air which enters the house requires 0.335 watt-hours of energy to heat it 1 Celsius degree.

Therefore air change heat loss = $191 \times 0.335 = 63.99$ W/°C.
Therefore the total heat loss factors (G factors) for the house, before and after upgrading, are as follows:
Base house: G = 209.78 + 63.99 = 274 W/°C
Upgraded house: G = 176.82 + 63.99 = 241 W/°C

This can also be expressed in megajoules (MJ) per hour per °C by multiplying by the factor 3.6×10^{-3}.
Therefore –

Base house: $G = 274 \times 3.6 \times 10^{-3} = 0.986$ MJ/hr-°C

Upgraded house: $G = 241 \times 3.6 \times 10^{-3} = 0.868$ MJ/hr-°C

What these factors mean is that if the temperature outside the base case house is 1°C colder than the inside temperature, then, every hour 0.986 megajoules of energy will flow outward through the roof, walls, windows, doors, an in the infiltration/exfiltration of air. If the outside temperature is 10°C colder then 9.86 megajoules will flow out in an hour, etc.

A.1.4 Step 4 – Calculate Annual Heating Costs and Savings

The degree-day value for a site provides a measure of how cold it is and for how long. Multiplying the G factor for the house by the degree-days gives an approximation of the gross energy loss from the house.
Therefore for the base house:

Gross Energy Loss $= 0.986 \times 4130 \times 24$ (to convert degree-days to degree-hours)
$= 97{,}700$ MJ

However as discussed in Subsection 2.1 only part of this loss is made up by the furnace. The rest, the "free heat", comes from the sun, from appliances and from the occupants themselves. Although the amount of free heat varies from household to household, a typical value would be 26,000 megajoules per year.
Therefore for the base house:

Energy supplied by furnace $= 97{,}700 - 26{,}000$
$= 71{,}700$ MJ

However the furnace, according to Table 5.1, is only 65% efficient on a seasonal basis. Therefore more energy is purchased than is actually supplied to the house.

Therefore purchased energy $= \dfrac{71{,}700}{0.65}$
$= 110{,}300$ MJ

and annual heating cost $= 110{,}300 \times 0.003$
$= \$331$

Similarly, for the upgraded house:

Gross Energy Loss $= 0.868 \times 4130 \times 24$
$= 86{,}000$ MJ

Energy supplied by furnace $= 86{,}000 - 26{,}000$
$= 60{,}000$ MJ

Ignoring, for the moment, the expected higher efficiency of the spark ignition furnace in the upgraded house,

Purchased energy $= \dfrac{60{,}000}{0.65}$
$= 92{,}300$ MJ

Annual heating cost $= 92{,}300 \times 0.003$
$= \$277$

Saving due to upgrading shell $= \$331 - \$277$
$= \$54$

To this is added the savings expected from the higher efficiency of the spark ignition furnace. Table 5.2 indicates that this varies between \$18 and \$22. Since this house is in a relatively mild area, we will use the lower figure.

Therefore TOTAL SAVINGS $= \$54 + \$18 = \$72$

A1.1.5 Step 5 – Calculate Payback Period
The builder, of course, is in the best position to calculate his own price premiums for upgrading measures. However to illustrate the payback process, we will use the price premiums given in the tables in Sections 4 and 5.

Total Cost Premium (C.P.)

Ceiling – Option 3 Table 4.7

$$\text{C.P.} = 126 \times \frac{86 \text{ (ceiling area this house)}}{70 \text{ (ceiling area Tables base house)}} = \$155$$

Walls – Option 6 Table 4.4

$$\text{C.P.} = 312 \times \frac{157 \text{ (wall area inc. 2nd storey header)}}{142} = \$345$$

Foundation – Option 8 Table 4.1

$$\text{C.P.} = 283 \times \frac{37.12 \text{ (perimeter)}}{33.5} = \$314$$

Spark ignition furnace	Table 5.2	$100
TOTAL		$914

$$\text{Ratio of Construction Price Premium to first year fuel cost savings} = \frac{914}{72} = 12.7$$

From Payback Chart Figure B.4 p.131 the payback period is in the range of 10-12.5 years.

A.2 NOTES ON THE HEAT LOSS CALCULATION METHOD

The method presented here was developed by Scanada Consultants Limited. It is based on standard methods such as ASHRAE or HRAI but modified empirically to fit the results of a number of field studies of actual energy consumption in houses. Its unique features concern air change, free heat, and below grade heat losses.

A.2.1 Air Change

The available data on the amount of air change experienced by houses is very limited. However what is available tends to indicate that ⅓ of an air change per hour is both a typical figure for modern, well insulated houses and a safe lower limit below which humidity problems will tend to appear. Thus even if the building shell were to be substantially tightened as recommended in Subsection. 4.1 so that accidental air change was reduced below ⅓ air change per hour, it would be necessary to bring total air change back up to or near this level by the introduction of controlled ventilation. Recent studies have also shown that, whereas insulating a previously uninsulated house can substantially improve its airtightness, going from "well insulated" to "better insulated" has no appreciable affect on airtightness.

Thus this method, as applied to new housing, makes no allowance for improvements in airtightness and, at the same time, saves time and effort by eliminating the elaborate crackage calculations of other methods.

No doubt new houses are being built that far exceed this ⅓ air change rate, but this is usually due to poor construction. It is impossible, using calculations alone, to predict the occurrence of such faults or to measure their effect.

A.2.2 Free Heat

The calculation method recognizes that, for a given household and basic house design and orientation, the heat contributed by appliances, occupants and the sun remains essentially constant, no matter what the gross heat loss of the house, and remains constant in absolute terms rather than in terms of a percentage of gross heat loss. Other methods often use a constant modifying factor for the degree days in calculating both base case and upgraded case heat losses and this tends to understate savings. This method does not modify the degree days but subtracts a constant amount from both the base and upgraded gross heat losses. If it is only desired to predict savings, as opposed to heating bills, then it is not necessary to assess the amount of free heat with much accuracy since it drops out of the savings calculation.

The above should be qualified to some extent. If a house design is substantially upgraded, then in the early fall and late spring the daily free heat contribution may well exceed the gross daily heat loss and it will be necessary to open windows to prevent the temperature from rising. In other words some of the free heat will be "spilled" and, in terms of its contribution to annual heating requirements it will not remain exactly constant. Within the range of upgrading covered by this Guide, this effect is likely to be very small and keeping the free heat constant is sufficiently accurate. This would not be true, however, for very large differences between the base and upgraded gross heat losses – where the latter is, say, less than half of the former.

A.2.3 Below Grade Heat Losses

As stated previously, this is an area where the current state of knowledge is very limited. The method used here is based on a model of below-grade heat losses developed by the National Research Council a number of years ago (Boileau, G.G. and Latta, J.K., "Calculation of Basement Heat Losses", National Research Council of Canada, Division of Building Research, NRC 10477, Dec. 1968). Recent field studies have indicated that this model is generally correct but, since it was originally developed for calculating instantaneous heat losses for design purposes, modifications have been introduced to adapt it to the calculation of annual heat losses.

Among these modifications is one that takes into account the fact that basement temperatures tend to be lower than those in principal living areas. For split-level houses and other styles where some of the principal living area is below grade, and higher temperatures are therefore maintained there, this method may tend to understate heat losses.

Appendix B
Data for Heat Loss Calculations

Table B.1
Degree Days of Selected Urban Areas

Urban Area	Degree Days Below 18°C	Urban Area	Degree Days Below 18°C
Barrie	4470	Peterborough	4520
Belleville	4190	Port Alberni	3180
Brandon	6037	Portage la Prairie	5890
Brantford	3920	Prince Albert	6562
Brockville	4300	Prince George	5388
Calgary	5345	Prince Rupert	4117
Charlottetown	4623	Red Deer	5700
Chatham (Ont.)	3530	Regina	5920
Chicoutimi	5510	Rimouski	5400
Corner Brook	4900	St. Catharines	3550
Cornwall	4470	St. Hyacinthe	4650
Dawson Creek	5890	St. Jean	4630
Drummondville	4740	Saint John	4771
Edmonton	5589	St. John's	4804
Flin Flon	6780	St. Thomas	3850
Fredericton	4699	Sarnia	3840
Granby	4580	Saskatoon	6077
Guelph	4220	Sault Ste. Marie	5180
Halifax	4123	Sept-Iles	6135
Hamilton	3710	Shawinigan	5110
Jonquiere	5720	Sherbrooke	5242
Kamloops	3756	Sorel	4840
Kelowna	3680	Stratford	4300
Kenora	5932	Sudbury	5447
Kingston	4266	Swift Current	5482
Kirkland Lake	6150	Sydney	4459
Kitchener	4110	Thetford Mines	5350
London	4068	Thunder Bay	5746
Medicine Hat	4874	Timmins	6189
Moncton	4709	Toronto	4082
Montreal	4471	Trail	3650
Moose Jaw	5400	Trois Rivieres	5070
Nanaimo	3010	Truro	4704
Niagara Falls	3740	Val d'Or	6146
North Battleford	6050	Vancouver	3007
North Bay	5318	Vernon	4040
Oshawa	4130	Victoria	3076
Ottawa/Hull	4673	Welland	3640
Owen Sound	4220	Windsor (Ont.)	3590
Penticton	3514	Winnipeg	5889

Values for other locations . . . (see footnote bottom of page 120)

FIGURE B·1
ANNUAL DEGREE DAYS
(BELOW 18°C)

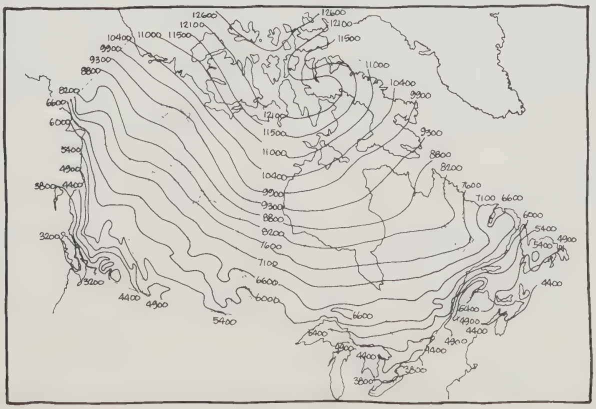


Table B.2 (from Builders' Bulletin #282, 1978-03-14)
Thermal Resistance Values of Various Building Materials[1]

Introduction

The thermal resistance of a building material or assembly is a complex property which varies with the temperature difference across the material or assembly and the mean temperature at which it is measured. The thermal resistance of air spaces is affected by these variables and also by the proportions of the space. While it may be necessary to take into account such variations when doing precise scientific calculations, such sophistication is not deemed justified for purpose of assessing compliance of housing designs with prescribed thermal resistance requirements.

The attached table provides thermal resistance values for various construction materials. These materials fall into two principal categories as follows:

- Materials which are assessed on a generic basis such as wood, concrete or bricks. The values given for this category are the only values officially recognized by CMHC.
- Materials which are assessed on a product-by-product basis. Most insulation materials fall into this category. The values given for this category are indicated by italics and are average values provided for guidance only. The values recognized by CMHC for specific products are given in CMHC's Acceptable Building Materials Systems and Equipment Manual (A.B.M.) which is available for examination at CMHC offices.

All values are given in m^2 °C/W

Thermal Resistance Values of Various Building Materials

Description	Thermal Resistance (R Value) For Effective Thickness
Air Surface Films	
Still Air-Horizontal Surface-Heat Flow Up e.g. inside of ceilings	0.105
Still Horizontal Surface-Heat Flow Down e.g. inside of floor	0.162
Still Air-Vertical Surface-Heat Flow Horizontal e.g. inside of wall	0.120
Moving Air – Any Position – outside of any surface	0.030
Air Spaces – Faced with Non-reflective Materials – 12 mm Minimum Dimension	
Horizontal Space-Heat Flow Up e.g. air space in flat roof	0.150
Horizontal Space-Heat Flow Down e.g. air space in floor	0.180
Vertical Space-Heat Flow Horizontal e.g. air space in wall	0.171
Air Spaces Less than 12 mm in Minimum Dimension	0
Air Spaces – Faced with Reflective Materials[2] – 12 mm Minimum Dimension	
Horizontal Space-Faced 1 Side-Heat Flow Up e.g. air space in flat roof	0.324
Horizontal Space-Faced 2 Side-Heat Flow Up e.g. air space in flat roof	0.332
Horizontal Space-Faced 1 Side-Heat Flow Down e.g. air space in floor	0.980
Horizontal Space-Faced 2 Side-Heat Flow Down e.g. air space in floor	1.034
Vertical Space-Faced 1 Side-Heat Flow Horizontal e.g. air space in wall	0.465
Vertical Space-Faced 2 Side-Heat Flow Horizontal e.g. air space in wall	0.480
Air Spaces Less than 12 mm in Minimum Dimension	0

	Thermal Resistance (R Value) Per mm of Thickness	For Thickness Listed
Insulation		
Mineral Wool and Glass Fibre	*0.0208*	
Cellulose Fibre	0.0253	
Vermiculite	*0.0144*	
Wood Fibre	*0.0231*	
Wood Shavings	*0.0169*	
Expanded Polystyrene Complying with CGSB 41-GP-14a (1972)		
– TYPE 1 beadboard	0.0257	
– TYPE 2 of increasing	0.0277	
– TYPE 3 densities	0.0298	
– TYPE 4–extruded	0.0347	

1 From CMHC Builders' Bulletin #282, 1978-03-14

2 These values may not be used in calculations for areas where the mean annual total degree days exceed 4400 celsius degree days

Table B.2 contd.

Insulation contd.

	Thermal Resistance (R Value) Per mm of Thickness	Thermal Resistance (R Value) For Thickness Listed
Rigid Glass Fibre Roof Insulation	0.0277	
Rigid Urethane or Isocyanurate Board	0.0504	
Mineral Aggregate Board	0.0182	
Compressed Straw Board	0.0139	
Fibreboard	0.0194	
Phenolic Foam	0.0304	
Structural Materials		
Softwood Logs and Lumber	0.0087	
Concrete		
– 2400 kg/m³	0.00045	
– 1760 kg/m³	0.0013	
– 480 kg/m³	0.0069	
Concrete Block – 3 Oval Core		
Sand and Gravel Aggregate		
– 100 mm		0.125
– 200 mm		0.195
– 300 mm		0.225
Cinder Aggregate		
– 100 mm		0.195
– 200 mm		0.302
– 300 mm		0.332
Lightweight Aggregate		
– 100 mm		0.264
– 200 mm		0.352
– 300 mm		0.400
Sheathing Materials		
Softwood Plywood	0.0087	
Mat-Formed Particle Board	0.0087	
Insulating Fibreboard Sheathing	0.0165	
Gypsum Sheathing	0.0062	
Sheathing Paper		0.011
Asphalt Coated Kraft Paper Vapour Barrier	Negligible	
Polyethylene Vapour Barrier	Negligible	
Roofing Materials		
Asphalt Roll Roofing		0.026
Asphalt Shingles		0.078
Built-up Roofing		0.058
Wood Shingles		0.165
Interior Finish Materials		
Gypsum Board. Gypsum Lath	0.0062	
Gypsum Plaster – Sand Aggregate	0.0014	
Gypsum Plaster – Lightweight Aggregate	0.0044	
Plywood	0.0087	
Hard-Pressed Fibreboard	0.0050	
Insulating Fibreboard	0.0165	
Mat-Formed Particleboard	0.0087	
Carpet and Fibrous Underlay		0.366
Carpet and Rubber Underlay		0.226
Resilient Floor Coverings		0.014
Terrazzo – 25 mm		0.08
Hardwood Flooring		
– 9.5 mm		0.060
– 19 mm		0.120
Wood Fibre Tiles		
– 13 mm		0.209

Table B.2 contd.

	Thermal Resistance (R Valu Per mm of Thickness	For Thicknes Listed
Cladding Materials		
Fibreboard Siding	0.0107	
Softwood Siding		
Drop – 18 × 184 mm		0.139
Bevel – 12 × 184 mm Lapped		0.143
Bevel – 19 × 235 mm Lapped		0.185
Plywood – 9 mm Lapped		0.103
Brick		
Clay or Shale 100 mm		0.074
Concrete and Sand/Lime 100 mm		0.053
Stucco 15 mm		0.021
Metal Siding		
Horizontal Clapboard Profile		0.123
Horizontal Clapboard Profile with Backing		0.246
Vertical V-Groove Profile		0.123
Vertical Board and Batten Profile		Negligible

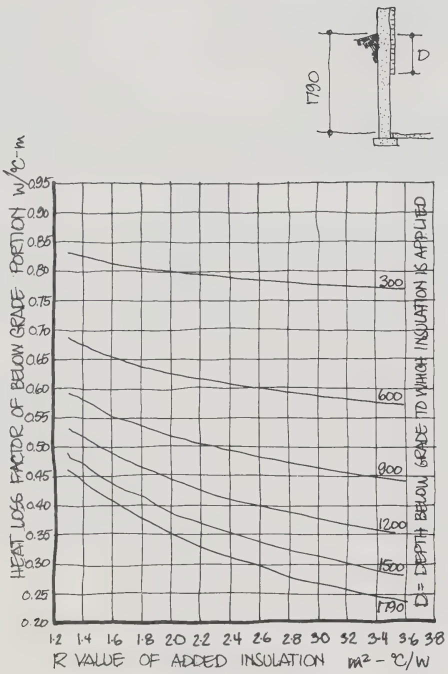


FIGURE B·2
BELOW GRADE HEAT LOSS FACTORS FOR FOUNDATION WALLS EXTENDING 1790 mm BELOW GRADE

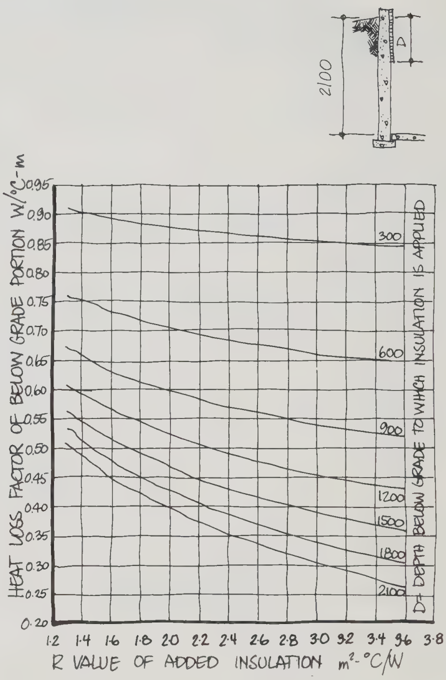


FIGURE B·3
BELOW GRADE HEAT LOSS FACTORS FOR FOUNDATION WALLS EXTENDING 2100 mm BELOW GRADE

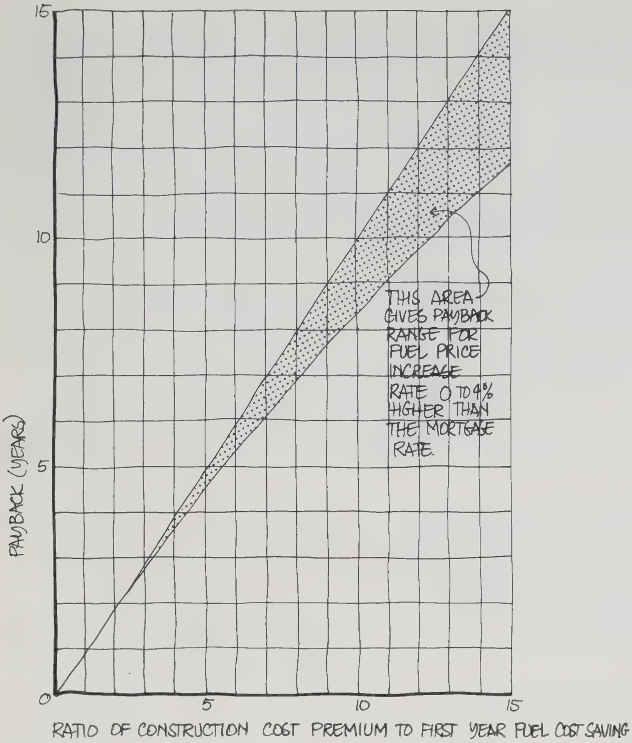


FIGURE B·4 PAYBACK CHART

APPENDIX C
ONTARIO BUILDING CODE REQUIREMENTS

Throughout the Guide there has been frequent reference to the Ontario Building Code (O.B.C.) which is used as a base case for many of the options examined. This appendix provides a brief summary of the relevant requirements of the O.B.C. in order that non-Ontario builders may have a better understanding of this base case.

Insulation Levels
The O.B.C. specifies the R value of the insulation which must be added to the various building elements rather than the total R value of the element. The requirements are as follows (paraphrased from Article 9.26.4.5 (1) and Table 9.25.4.A):

Building Element	R Value of Insulation
-concrete or masonry foundation walls	1.41
-preserved wood foundation walls	2.11
-floors over unheated space and floor overhangs	3.52
-walls	2.11
-attic-type roofs	4.93
-flat and cathedral roofs	3.52
-perimeter of slabs-on-grade	
- containing heating ducts or pipes	1.76
-not containing heating ducts or pipes	1.41

Other Requirements
9.26.4.4. Insulation around concrete slabs-on-grade shall extend not less than 600 mm below exterior ground level and be located so that heat from the building is not restricted from reachiing the ground beneath their perimeter where exterior walls are not supported by footings extending below frost level.

9.26.5.5.(1) The upper part of foundation walls enclosing heated space shall be insulated from the underside of the subfloor to not less than 600 mm below the finished ground level.
(2) If a foundation wall is constructed of hollow masonry units, one or more of the following shall be used to control convection currents in the core spaces,
(a) filling the core spaces;
(b) laying at, or below grade at least one layer of polyethylene between two courses of blocks;
(c) at least one row of semi-solid blocks at or below grade, or
(d) other similar methods.

9.26.5.6.(1) Insulation for the below-grade portion of the interior of foundation walls shall be protected from moisture by a moisture barrier or be inherently moisture resistant and batt-type insulation shall be additionally protected by a vapour barrier.
(2) Insulation on the inside of such foundation walls shall be installed tightly against the foundation wall and shall be sealed at the top and at the bottom to reduce air circulation.

9.26.5.7. Insulation shall be installed in such a manner so as not to impede the free flow of air between soffit vents and through attic and roof spaces.

9.26.5.11(1) Except where insulation is installed on a roof deck the required clearance between the underside of the roof deck and the top of insulation shall be at least 152 mm for roof systèms,
(a) with a slope of 2 in 12 or less, and
(b) with a slope more than 2 in 12 where the interior finish is applied to the underside of roof framing members that span from ridge to exterior wall plate.

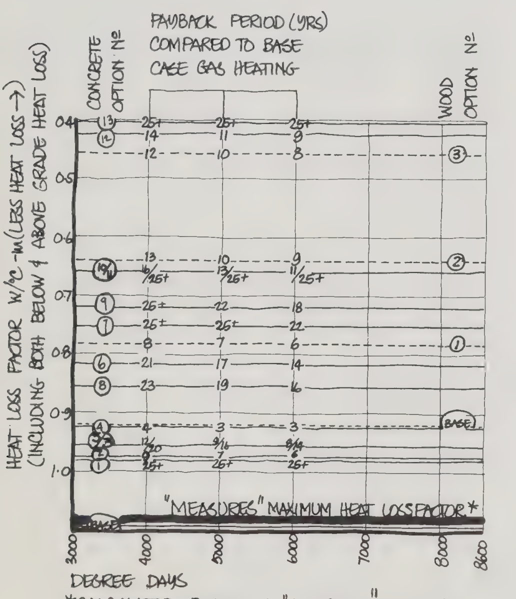
APPENDIX D
COMPARISON OF INSULATION OPTIONS WITH "MEASURES FOR ENERGY CONSERVATION IN NEW BUILDINGS"

"Measures for Energy Conservation in New Buildings" was published in 1978 by the Associate Committee on the National Building Code. Like the National Building Code, it is a model document with no force unless adopted by an authority such as a municipality, a province, or Canada Mortgage and Housing Corporation. At time of publication of the Guide, no such authority had adopted the "Measures" but it seemed likely that it would eventually be adopted by at least some authorities. This appendix is provided, therefore, to assist builders who may be required to comply with the "Measures".

Figures D.1 to D.5 show the relationship between the various insulation options in Section 4 and the minimum R values included in the "Measures". The payback periods from the tables in Section 4 are included for guidance as to which option might be the most economical choice for complying with the "Measures".

For example, consider the choice of a wall insulation option for a house in a 6000 degree day area. Figure D.3 shows that options 6, 7, 8, 9, 10, 11, 12, 13 and 14 all exceed the minimum R value required for a 6000 degree day area. Option 8 provides the fastest payback (3 years) even though it exceeds the minimum by a greater margin than Options 6 and 7 (11 and 9 years payback respectively). (Note that the payback is measured relative to the base case not to the "Measures" minimum.) Thus Option 8 is likely to be the most economical means of complying with the "Measures" in a 6000 degree day area provided—

a) the builder's cost confirm those used in the Guide, and
b) the option is compatible with the builder's construction practices.



*CALCULATED BASED ON "MEASURES" MINIMUM R VALUE (1.6) AND DEPTH (600 mm BELOW GRADE) AND USING FIGURE B-2

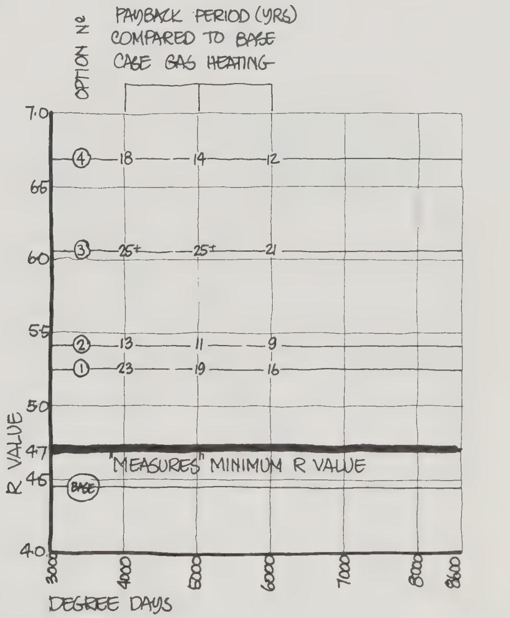


FIGURE D·1
COMPARISON OF FOUNDATION INSULATION OPTIONS WITH "MEASURES FOR THE CONSERVATION OF ENERGY IN NEW BUILDINGS"

FIGURE D·2
COMPARISON OF FLOOR INSULATION OPTIONS WITH "MEASURES FOR ENERGY CONSERVATION IN NEW BUILDINGS"

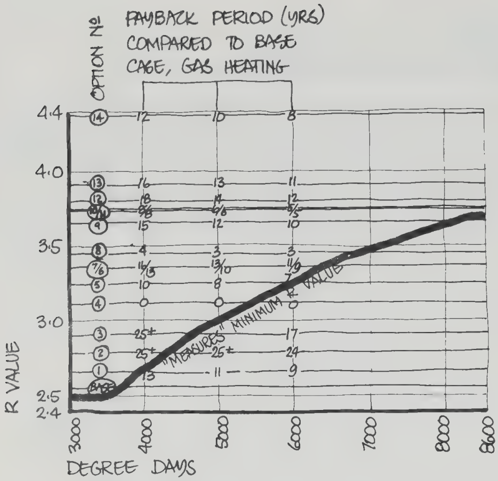


FIGURE D·3

COMPARISON OF WALL INSULATION OPTIONS WITH "MEASURES FOR ENERGY CONSERVATION IN NEW BUILDINGS

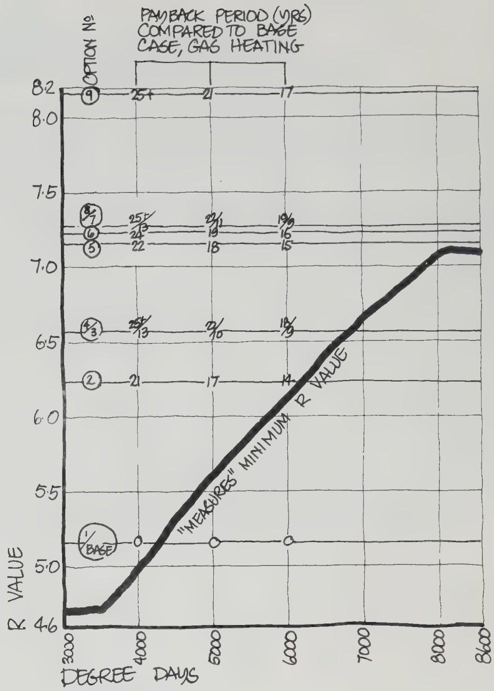


FIGURE D·4

COMPARISON OF ATTIC-TYPE ROOF INSULATION OPTIONS WITH "MEASURES FOR ENERGY CONSERVATION IN NEW BUILDINGS"

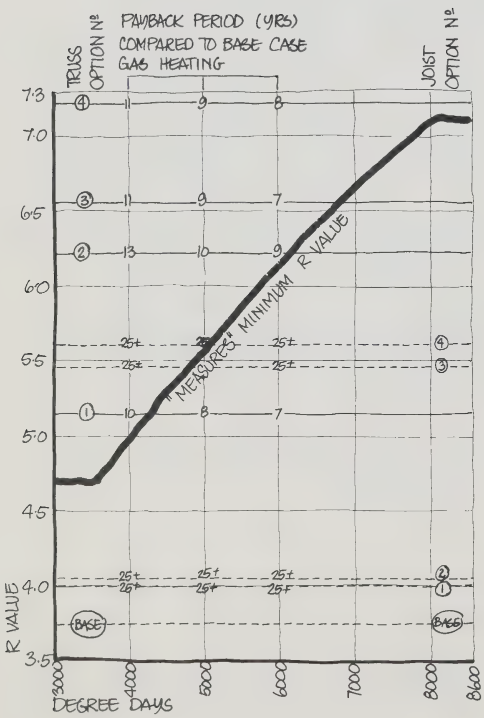


FIGURE D·5

COMPARISON OF FLAT & CATHEDRAL ROOF INSULATION OPTIONS WITH "MEASURES FOR ENERGY CONSERVATION IN NEW BUILDINGS"

APPENDIX E
ABBREVIATIONS AND CONVERSION FACTORS

°C degrees celsius

DD: degree days (The total annual degree days is the sum of the differences between 18°C and the mean temperatures in °C of every day in the year when the mean temperature is below 18°C)

F.F.: friction fit

G: overall heat loss factor for the dwelling expressed in MJ/hr.–°C orW/°C

GJ: gigajoule (1 gigajoule = 1,000 megajoules)

H.L.F.: annual heat loss factor expressed in watts per degree celsius per metre = W/°C-m

J: joule

kg: kilogram (1 kilogram = 2.2 pounds)

kWh: kilowatt-hour (1 kWh = 3.6 MJ = 3,413 British Thermal Units)

L: litre (1L = 0.0353 cubic feet, 1L = 0.220 imperial gallons)

MJ: megajoule (1MJ = 1,000,000 J = 947.8 British Thermal Units)

m^2: square metres (1m^2 = 10.76 square feet)

m^3: cubic metres (1m^3 = 35.314 cubic feet = 1,000 litres)

min: minimum

Pa: Pascal (1 Pascal = 1 Newton per square metre = 145.03 pounds per square foot)

P.B.: paper backed

R: resistance to heat flow, expressed in metric units as m^2 °C - W

R: (in metric units) = R(SI) = 0.176 R (in imperial units)

W: watt (1 watt = 1 joule/second)

ASHRAE: American Society of Heating, Refrigeration and Airconditioning Engineers

CHVAC: Canadian Heating, Ventilation and Air-Conditioning Code

CMHC: Canada Mortgage and Housing Corporation

CSA: Canadian Standards Association

HRAI: Heating Refrigeration and Airconditioning Institute

ULC: Underwriter's Laboratories of Canada

1L of #2 fuel oil provides a heating value = 38 MJ

1m^3 of natural gas provides a heating value = 37 MJ

INDEX